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REVISION OF THE PRIMITIIDAE AND BEYRICHIIDAE, WITH NEW OSTRACODA FROM THE LOWER DEVONIAN OF PENNSYLVANIA

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ABSTRACT

The old families Primitiidae and Beyrichiidae are subdivided into six families: Primitiidae (emended), Beyrichiidae (emended), Hollinidae, Tetradellidae, Drepanellidae, and Acronotellidae. A seventh family, the Aechminidae, is doubtfully assigned to this group, and an eighth, the Primitopsidae, is proposed provisionally. The genera belonging to each family are listed. The question of the orientation of the Primitiidae and related forms is discussed.

The new genera *Paraschmidtella*, *Milleratia*, *Pyxiprimitia*, *Parabolbina*, *Tubulibairdia*, and *Kellettina* are proposed. Part of the ostracode fauna of the Lower Devonian Shriver chert of Pennsylvania is described.

The Lower Devonian Shriver chert of western Maryland and central Pennsylvania contains a large and varied ostracode fauna, which should provide valuable assistance in clarifying the still uncertain relations of the formation to the Lower Devonian beds of New Jersey, southeastern New York, and parts of Maryland and Virginia. Eleven species occurring in the Shriver in western Maryland were described by Ulrich and Bassler in 1913 (1). Two of these were redescribed by the writer in 1932, along with nine new species belonging to the family Thlipsuridae (2). Additional new ostracodes from the Shriver of central Pennsylvania form the basis of the present paper, and their study has led to the proposal of revisions of the Primitiidae and Beyrichiidae, as heretofore understood.

Acknowledgments(3).—The writer is indebted to the Geological Society of America for a grant from the Penrose Bequest which provided for the services of Mr. Gordon Jacober in preparation of material and illustrations. The School of Mineral Industries of the Pennsylvania State College provided laboratory facilities. Mr. Glen Burgener helped to collect material at Hollidaysburg and Lewistown, and studied some of the material from Lewistown for his undergraduate thesis. Dr. R. S. Bassler kindly made suggestions concerning the generic relations of several of the species, and provided the specimens of *Milleratia cincinnatiensis*. Dr. J. H Bonnema loaned the types of *Primitia bonnema*, and has permitted illustration of his specimens. Dr. T. H. Withers provided illustrations of, and information concerning, the holotype of *Primitia mundula*. Dr. C. K. Swartz has made valuable suggestions concerning the section on revision of the Primitiidae and Beyrichiidae.

The manuscript was received by the editor through the secretary of the Geological Society of America, December 19, 1935.

STRATIGRAPHIC RELATIONS OF THE SHRIVER SPECIES

The Shriver species described in this paper were collected at sections

near Hollidaysburg, Lewistown, Curtin, and Jersey Shore, all in central Pennsylvania. At these localities the Shriver is about 120 to 130 feet thick. It is overlain by the Ridgeley sandstone, carrying a typical Oriskany fauna with *Spirifer arenosus* and *Spirifer* (*Hysterolites*) *murchisoni*, and is underlain by the New Scotland limestone of the Helderberg group, with *Spirifer* (*Eospirifer*) *macropleurus*. In the area studied, the Shriver contains little true chert, although the beds are very siliceous. The silica is so finely divided that the natural impressions in the weathered rock preserve the ornamentation in remarkable detail, as is shown by the accompanying photographs of squeezes made with dental temporary stopping.

In the four sections, the most persistent ostracodes are *Bollia sagittaformis*, *Bollia burgeneri*, *Bollia americana* var. *zygocornis*, *Bollia cristata*, *Thlipsura confluens*, *Thlipsura robusta* var. *tricornis*, *Thlipsurella secoclefta*, *Thlipsurella oblonga*, *Thlipsurella orthoclefta*, and *Acanthoscapha pentagonalis*. Of these, *Bollia sagittaformis*, *Bollia burgeneri*, and *Acanthoscapha pentagonalis* appear to be restricted to the middle part of the Shriver, while the remainder range from the middle to the upper beds of the formation. Other species have been found more rarely, and their ranges are consequently less well established. No ostracodes have been obtained from the lower third of the Shriver at the four localities in Pennsylvania.

Of the eleven ostracodes described by Ulrich and Bassler from the Shriver of western Maryland, five have now been found in central Pennsylvania. An additional species, *Thlipsurella orthoclefta*, occurs in the Shriver in both areas, and further studies of the Shriver of Maryland should lead to the discovery of still other species now known only in Pennsylvania.

The writer recently obtained the Shriver species *Thlipsurella secoclefta*, *T. oblonga*, and *Thlipsura* cf. *T. robusta*, in loose impure cherts 40 to 50 feet above the New Scotland limestone at Monterey, Virginia. These species support the view that the chert beds are a southern continuation of the Shriver; although they pass laterally into the lower part and are overlain by the upper part of a limestone which has been considered pre-Shriver in age by Maryland geologists (4).

It is particularly desirable to have work done on the ostracodes of the Helderberg and Oriskany beds of New Jersey and southeastern New York. The middle part of the Shriver of central Pennsylvania contains an abundance of the brachiopod *Metaplasia plicata* Weller. In New Jersey, this species occurs principally in the *Orbiculoidea jervensis* zone of the lower part of the Oriskany group, below the *Spirifer* (*Hysterolites*) *murchisoni* beds. This zone should be carefully searched for Shriver ostracodes. One of the Shriver species, *Bollia americana* var. *zygocornis*, has been figured from the Oriskany of Becraft Mountain, New York, by J. M. Clarke.

REVISION OF THE PRIMITIIDAE AND BEYRICHIIDAE

The Shriver species described in this paper belong largely to genera included in the family Primitiidae by Ulrich and Bassler, in their classic work on Paleozoic ostracodes published in 1923 (6). The arrangement of this family has consequently been of especial interest and Primitiidae in the Ulrich and Bassler collections at the U. S. National Museum have been examined at various times as part of the investigation.

Among the specimens in the above collections are "topotypes" of *Primitia mundula* (Jones), the genotype of *Primitia*, and hence the species around which the family Primitiidae has been erected. These "topotypes" were obtained from the Silurian drift of Germany, and were provisionally identified as *P. mundula* by Krause. The best specimen is a well preserved carapace, which is straight-backed, the valves strongly unequal, with rather regularly convex, very weakly unisulcate surfaces (Pl. 86, figs. 5 *a–c*). Because of the latter features, this carapace departs widely from Ulrich and Bassler's analysis of *Primitia*, which reads (5*a*):

> Distinguished from *Primitiella* by having a well marked subcentral, usually curved sulcus with undefined swellings or low nodes on one or both sides of it instead of an undefined depression.

Primitiella (5*b*) is said to include

> Small, straightbacked, equivalved shells with a broad undefined median depression mainly in the dorsal half of the valves, and with narrow border.

Primitia is illustrated by *P. cincinnatiensis* (Miller), which is cited as a typical American species of the genus.

It was, therefore, clear that if Krause's specimen really represents *P. mundula*, Ulrich and Bassler's conception of *Primitia* would have to be greatly modified, and the family Primitiidae reorganized, at least if that name is to be retained. A photograph of Jones' holotype in the Jones collection of the British Museum of Natural History was subsequently obtained through the courtesy of Dr. T. A. Withers, along with sketches of the dorsal and terminal outlines (Pl. 86, figs. 4*a–c*). The holotype is a distinctly unisulcate convex valve, without apparent swellings near the sulcus or elsewhere, and without any marginal border. Unfortunately, it provides no direct data on hingement or marginal overlap, and, according to Dr. Withers, the cardinal angles are imperfect. Like Krause's specimen, Jones' holotype was obtained from a slab of Silurian drift, found in Germany, so that there is no type locality or horizon from which additional material can be obtained. Two other specimens, apparently from the same piece of drift, give no further information.

The writer also corresponded with Dr. J. H. Bonnema, who very kindly loaned specimens from the Silurian of Gotland, tentatively identified as *P. mundula*. The Gotland material differs in certain respects from Jones' type, and is here described and illustrated as *P. bonnemai* (Pl. 86, figs. 6

a–g). It is, however, so close to *P. mundula* that it can well be considered a thoroughly typical representative of the genus. Normally, the median sulcus is a well defined, vertical, dorso-median furrow. The surface of the valve is strongly convex, but has a broad, shallow median depression. There is no border, and there are no localized swellings. The hinge is relatively simple, and there is no appreciable marginal overlap. There is no evidence of sexual dimorphism in the specimens examined by the writer.

From the study of Jones' holotype and of *P. bonnemai*, it is clear that Krause's specimen, referred to above, can not be considered a member of *Primitia*, or even of the Primitiidae; although a separate valve supplied by Krause evidently belongs to the genus, and is, indeed, close to *P. mundula*. Furthermore, as is shown elsewhere, *Primitia cincinnatiensis* (Miller) (Pl. 86, figs. 7 *a–e*) is not a typical member of *Primitia*. Instead, it possesses strong dorsal humps, and is here made the type of a new genus for which the name *Milleratia* is proposed. It is evident that further studies of the species currently referred (7) to *Primitia* will be required before that genus will be well understood.

Turning to the Primitiidae as a whole, the analysis given by Ulrich and Bassler, when they erected this family in 1923, reads as follows (5*b*):

"Relatively simple Beyrichiacea with undefined to well defined median sulcus or submedian pit."

In the same paper the family Beyrichiidae, was restricted to genera with

"valves trilobate or quadrilobate, deeply sulcated; brood pouch, when present, subglobular or egg-shaped, on the ventral slope"

(5*c*).

As indicated by the above descriptions, the strength of sulcation and lobation was accorded high value in the arrangement of the Primitiidae and Beyrichiidae. The brood pouches mentioned in the analysis of the Beyrichiidae were actually given little consideration, since they occur in only three of the eight genera included in the family.

In the writer's opinion, the degree of sulcation and lobation is of questionable genetic significance, and must be used with caution. Ulrich and Bassler found it to be relatively unimportant in the Kloedeninae and Kloedenellidae, which seem to be natural groups. In the latter family especially, there is wide variation from non-sulcate, through unisulcate and disulcate, to strongly trisulcate genera. Close genetic interrelationship is shown, however, by the subrhomboidal outline of the carapace, the persistent marginal overlap, the terminal female swellings, and, to a considerable extent, by the character of the surface lobation, which is dominated by the one, two, or three vertical sulci (Pl. 84, figs. 2*a–l*) (5*d*) (8).

In the Beyrichiidae, as revised by Ulrich and Bassler in 1923, one of the most striking and persistent features of the species currently referred to *Beyrichia* is the development of the strong globular subventral female pouches which are mentioned by Ulrich and Bassler in their descrip-

tion of the family. The lobation is much less stable (Pl. 78). Similar pouches occur in *Dibolbina* and *Treposella;* but, as has been pointed out, are unknown in the five additional genera included in the Beyrichiidae by the above authors. On the other hand, closely similar pouches are found in the females of the genera *Chilobolbina* and *Apatobolbina*, referred by Ulrich and Bassler to their subfamily Eurychilininae of the Beyrichiidae; while the elongate swelling of the frill of *Eurychilina ventrosa* apparently indicates the development of a primitive pouch in that genus (Pl. 78). Furthermore, these genera persistently develop a marginal frill, which typically is radially striate, and is closely similar to the frills of species of *Beyrichia* and *Dibolbina*. In the writer's opinion, these pouches represent an anatomical structure more fundamental than the degree of lobation, and more indicative of genetic relationship; especially when the pouches occur in combination with the peculiar marginal frill. The writer accordingly proposes to transfer the Eurychilininae of Ulrich and Bassler, including some primitively pouchless but frilled genera, from the Primitiidae to the Beyrichiidae; and at the same time to remove from the Beyrichiidae various strongly sulcate genera, which lack both the pouches and comparable frills.

The Beyrichiidae, as here arranged, are closely related to the Zygobolbidae, both families being characterized, except for the primitive genera noted above, by the subventral female pouches which are unknown in other ostracodes. It may therefore prove desirable to restrict the term superfamily Beyrichiacea, to these two families. Although the details are not yet clear, the Silurian and Devonian Zygobolbidae presumably evolved from the Ordovician to Devonian Beyrichiidae. As noted under the subsequent description of the Beyrichiidae, there is some uncertainty concerning use of the term *Beyrichia*, which may affect the use of the term Beyrichiidae for the family as here arranged.

The treatment of the Beyrichiidae proposed above necessitates removal of a considerable number of the genera included in the family by Ulrich and Bassler in 1923, and by Bassler and Kellett in 1934 (*7b*). Two alternate classifications have been considered. The first would place the majority of these genera in the *Primitiidae*, expanding that family to include all straight-backed, distinctly sulcate Ostracoda lacking the subventral dimorphic pouches of the Beyrichiidae and Zygoblobidae, and the terminal dimorphic swellings of the Kloedenellidae. This treatment, however, makes the Primitiidae excessively large and diversified as compared to other recognized Paleozoic families. Indeed, even with the transfer of the eurychilinids to the Beyrichiidae, and without the genera here removed from that family, the Primitiidae of Ulrich and Bassler include a considerable number of genera which represent marked specialization along several distinct lines of development.

It has accordingly seemed desirable to restrict the Primitiidae to genera agreeing with the analysis presented by Ulrich and Bassler in 1923; thus reducing the family to a plexus of primitive, simply sulcated, straight-backed Ostracoda, which have not developed structures definitely allying them with the more specialized groups. The majority of the genera which are removed from the Beyrichiidae are placed in two

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EXPLANATION OF PLATE 78

Family BEYRICHIIDAE (p. 547)

FIGS. *1*—*Coelochilina* Ulrich and Bassler, valve of genotype, *C. aequalis* (Ulrich), ×16. Ordovician, Stones River limestone, High Bridge, Ky.

2—*Apatochilina* Ulrich and Bassler, valve of genotype, *A. obesa* (Ulrich), ×18. Ordovician, Black River limestone, High Bridge, Ky.

3a–c—*Eurychilina* Ulrich. *3b, c*, Shows an elongate swelling in the ventral part of the frill, probably representing a primitive female pouch, and a strong median knob, suggestive of *Craspedobolbina* (7a, b). *3a*, Valve of genotype, *E. reticulata* Ulrich, ×14. Ordovician, Black River, Decorah shale, Fillmore County, Minn. *3b, c*, Side and end views of female (?) valve of *E. ventrosa* Ulrich, ×14. Ordovician, Trenton, Prosser shales, Cannon Falls, Minn.

4a, b—*Chilobolbina* Ulrich and Bassler, male and female valves of the genotype, *C. dentifera* (Bonnema), ×15. Ordovician, Kuckers formation, Kuckers, Esthonia.

5a, b—*Bolbibollia* Ulrich and Bassler, male and female valves of the genotype, *B. labrosa* Ulrich and Bassler, ×20. Silurian, Jupiter River formation, Jumpers, Island of Anticosti.

6a, b—*Apatobolbina* Ulrich and Bassler, male and female valves of the genotype, *A. granifera* Ulrich and Bassler, ×12. Silurian, Rose Hill shale, near Hollidaysburg, Pa.

7a, b—*Craspedobolbina* Kummerow, male and female valves of genotype, *C. deitrichi* Kummerow, ×25. Ordovician drift, Leptaena limestone, Brandenburg, Germany.

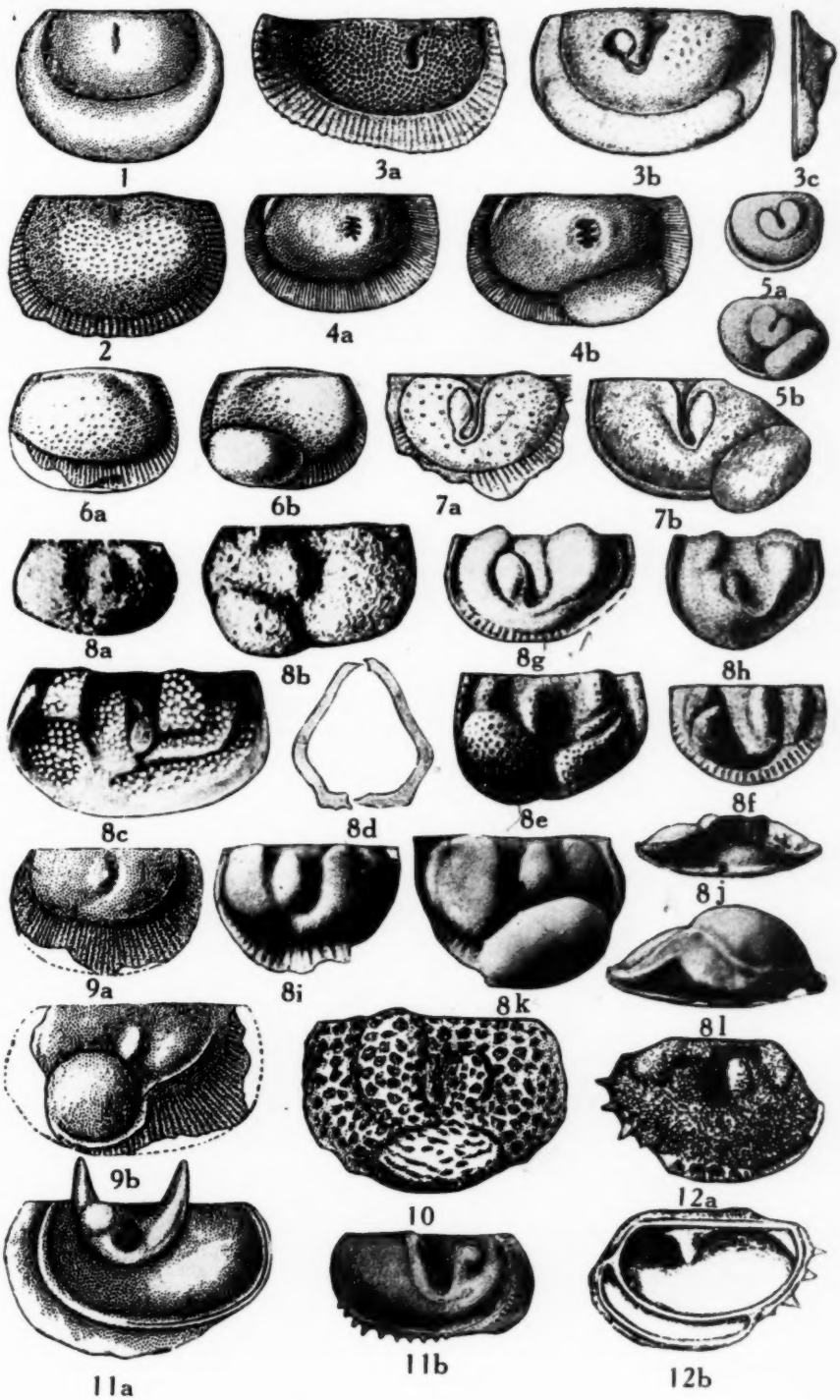
8a–l—*Beyrichia* McCoy, showing wide range in lobation in species now included in the genus, and variations in development of the frill. In *8g, h*, the median lobe is suggestive of *Craspedobolbina* and *Eurychilina*. In *8f*, the lobation is tending toward that in *8c*, but the radial frill is still well developed. In *8k* and *l*, it is clear that the female pouch is essentially a swollen part of the frill. *8d* shows the hinge and marginal relations, as determined by Bonnema. *8a, b*, Internal casts of male and female valves of the selected genotype, *B. kloedeni* McCoy, ×9. After Straw. Silurian, Upper Llandovery, Ireland. Note obsolesence of the frill, and lack of the depression ventral to the median lobe, which is well shown in *8i*. Ulrich and Bassler (6a) state that McCoy considered "*Battus tuberculatus*" Klöden (*8c–e*) a synonym of *B. kloedeni*, and that it is difficult to say which should be considered the genotype. *B. kloedeni* is not clearly congeneric with the other species here used to illustrate *Beyrichia*. *8c–e*, Side view of male valve ×10, vertical section of male carapace, as from right end of *8c*, ×12, and side view of female, ×6, of *B. tuberculata* (Klöden). Silurian, Europe. *8f*, Male valve of *B. maccoyiana sulcata* Reuter, ×12. Silurian, East Prussia. *8g*, Male valve of *B. clavata* Kolmodin, ×12±. Silurian, Europe. *8h*, Male valve of *B.* (?) *interrupta* (Jones), ×15. Silurian, Wenlock, England. *8i–l*, side and ventral views of male and female valves of *B. moodeyi* Ulrich and Bassler, ×15. Silurian, McKenzie formation, 3 miles east of Montoursville, Pa.

9a, b—*Dibolbina* Ulrich and Bassler, male and female valves of genotype, *D. cristata* Ulrich and Bassler, ×20, Silurian, Tonoloway limestone, Keyser, W. Va.

10—*Treposella* Ulrich and Bassler, female valve of genotype, *T. lyoni* (Ulrich), ×20. Devonian, Onondaga limestone, Falls of the Ohio River.

11a, b—*Dicranella* Ulrich, *11a*, valve of genotype, *D. bicornis* Ulrich, ×20. Ordovician, Decorah shale, Minneapolis, Minn. *11b*, valve of *D. spinosa* Ulrich, ×20. The striate remnant of the frill is suggestive of *Eurychilina*. Ordovician, Decorah shale, Minn.

12a, b—*Bromidella* Harris, exterior and interior of valve of genotype, *B. reticulata* Harris ×24. Ordovician, Oil Creek or Bromide formation, Oklahoma.



Swartz, Family Beyrichiidae

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new families, for which the names Hollinidae and Tetradellidae are here proposed. With the exception of the Eurychilinids, most of the specialized genera which are removed from the Primitiidae are referred to the new families Drepanellidae and Aechminidae; while several markedly aberrant genera are placed in the small family Acronotellidae and the provisional family Primitiopsidae.

Since dimorphism is almost wholly unknown in the genera placed in these proposed families, and the hinge and marginal structures are for the most part simple or poorly known, the arrangement outlined above is based principally upon supposed relationships inferred from the character—but not from the strength—of the ornamentation, including sulci, lobes, frills, and strong persistent spines. It is hoped that the treatment here proposed represents an advance over the classification hitherto in use; but with present knowledge it must be admitted that the interrelationships of many of these ostracodes are not yet firmly established. The difficulties of determining the lines of development of racial stocks, and the criterion which must form the ultimate basis of classification, have been well summarized by Ulrich and Bassler in their discussion of the Zygobolbidae, where they state (5*a*):

> Obviously, then, the subject of genetic relationships is always exceedingly intricate and liable to misinterpretation. For the same reasons, any classification of organisms that pretends to express natural affiliations is fraught with difficulties and loaded with inadequately determined associations. This is true perhaps particularly of the Ostracoda. Though the framework be largely of unassailable fact, the filling is mainly of unrecognized half-truth and frank uncertainty. Things that look unalike but really are near kin are widely separated, whereas others that originated from distinct sources are associated in the same genus or family because they possess certain features wrongly supposed to be diagnostic. Mainly perhaps because of the absence of soft parts, the fossil history of every class of organisms is yet far from being understood; and as the only sure means of advancing toward a better understanding is by working out the intergradation of species, progress necessarily is slow and by small steps.

The characters of the Beyrichiidae and Primitiidae, as here emended, and of the new families Hollinidae, Tetradellidae, Drepanellidae, Aechminidae, Acronotellidae, and Primitiopsidae, are presented more fully in the following descriptions. The order of treatment is intended to promote clarity of discussion, and is not meant to be biologic.

Family BEYRICHIIDAE Ulrich, 1894

Emended—Swartz, 1936

Semicircular to dorsally truncated subovate Ostracoda, with long straight hinge, and with both cardinal angles well defined; typically with a broad radially striate frill paralleling the whole free margin, although this frill becomes obsolete in some later species. Surface of valves non-sulcate, unisulcate, or disulcate, the more strongly sculptured genera tending to develop a prominent submedian elliptical lobe adjacent to the median sulcus. The earlier genera include species without known dimorphic structures, and species in which there is an elongate dimorphic swelling in the marginal frill, which probably served as a brood pouch. The females of the later more typical genera developed strong, oval or globular, subventral pouches, in-

timately related to the frill. Hingement relatively simple; overlap not conspicuous.

The following genera appear to be unquestionable members of the family, and are illustrated on Plate 78:

Coelochilina (9) Ulrich and Bassler; Ordovician; genotype *Eurychilina aequalis* Ulrich.

Apatochilina Ulrich and Bassler; Ordovician; genotype *Eurychilina obesa* Ulrich.

Eurychilina Ulrich; Ordovician; genotype *Eurychilina reticulata* Ulrich.

Chilobolbina Ulrich and Bassler; Ordovician, Silurian; genotype *Primitia dentifera* Bonnema.

Apatobolbina Ulrich and Bassler; Silurian; genotype *Apatobolbina granifera* Ulrich and Bassler.

Bolbibollia Ulrich and Bassler; Silurian; genotype *Bolbibollia labrosa* Ulrich and Bassler.

Craspedobolbina Kummerow; Ordovician; genotype *Craspedobolbina deitrichi* Kummerow.

Beyrichia McCoy; Silurian, Devonian; genotype *Beyrichia kloedeni* McCoy (39).

Dibolbina Ulrich and Bassler; Silurian; genotype *Dibolbina cristata* Ulrich and Bassler.

Treposella Ulrich and Bassler; Middle Devonian; genotype *Beyrichia lyoni* Ulrich.

The first two genera of the above list, and probably some species of *Eurychilina* are early forms, still devoid of female pouches, so far as known. In *Eurychilina* a female pouch is apparently represented by the elongate swelling of the frill of *E. ventrosa* (7*b*); although, so far as the writer knows, no associated dimorph without this swelling has yet been recognized. The remaining genera exhibit well developed pouches.

The following additional genera are tentatively included in this family:

Dicranella Ulrich; Ordovician; genotype *Dicranella bicornis* Ulrich. This genus may be an offshoot from the early non-dimorphic members of the family (10).

Bromidella Harris; Ordovician; genotype *Bromidella reticulata* Harris. The partial, non-striate frill appears to have an elongate swelling, suggestive of that of *Eurychilina ventrosa*. *B. reticulata* is an abundant species in the Bromide formation of the Arbuckle Mountains, but an associated non-pouched dimorph was not recognized by Harris.

The family Beyrichiidae, as here arranged, appears to the writer to be an assemblage of genera of especially clear genetic relationships. Unfortunately, however, the use of the name Beyrichiidae is complicated by questions concerning *Beyrichia* and its genotype. This genus was proposed by McCoy in 1846 (12), when he described *B. kloedeni* (Pl. 78, figs. 8*a*, *b*). According to Ulrich and Bassler, McCoy considered *B. kloedeni* a synonym of *Battus tuberculatus* (Pl. 78, figs. 8*c–e*), so that, in their opinion, either species might well be considered the genotype (6*a*). Since publication of Ulrich and Bassler's discussion in 1908, *Beyrichia* has been used primarily to include such species as *B. tuberculata* and *B. moodeyi* (Pl. 78, figs. 8*i–l*). It seems clear that *B. tuberculata* is a derivative of the section represented by *B. moodeyi*. Although the frill is nearly obsolete, and the ornamentation more complex, *B. tuberculata* retains the fundamental plan of lobation seen in *B. moodeyi*, and the two are connected by such forms as *B. maccoyiana sulcata* (Pl. 78, fig. 8*f*). On the other hand, *B. kloedeni* not only lacks the frill of *B. moodeyi*, but also has no suggestion of the depression on the ventral slope below the median lobe, which is characteristic of that species and its closest relatives (Pl. 78, figs. 8*i*, *f*). The lobation is consequently suggestive of the species now included in *Kloedenia* Jones and Holl, which also have strong subventral female pouches.

If further studies support the view that the relationships of *B. kloedeni* lie with *Kloedenia*, as now understood, rather than with *B. tuberculata* and *B. moodeyi*, it will be necessary either (1) to place the two latter species in one or two new genera, and rename the family

here described; or else (2) to consider *B. tuberculata* the genotype of *Beyrichia*—if McCoy's discussion is such as to permit this under the rules of nomenclature—and to refer *B. kloedeni* to *Kloedenia* (39).

With the revision of the Beyrichiidae proposed above, it is necessary to place elsewhere many of the genera included in the family by Ulrich and Bassler in 1923, and by Bassler and Kellet in 1935. *Ctenobolbina*, *Hollina*, *Hollinella*, and *Janischewskya* are referred to the new family Hollinidae, and are further discussed elsewhere. *Tetradella*, *Ceratopsis*, and *Kiesowia* are similarly placed in the new family Tetradellidae. The Pennsylvanian genus *Aechminella* Harlton appears to the writer to be closely allied to such forms as *Amphissites nodosus* Harlton, and evidently should be referred to the Kirkbyidae. This may also prove to be the proper place for the Pennsylvanian *Cornigella* Warthin, in spite of its similarity to *Aechimna*. The European Upper Devonian genus *Tetrasulcata* Matern may belong in the Kloedenillidae. The Silurian *Eoconchoecia* Moberg appears to be related to the Late Ordovician *Acronotella* Ulrich and Bassler, and these two genera are provisionally placed in the new family Acronotellidae. The Ordovician genus *Hippa* Barrande is referred tentatively to the Primitiidae. The disulcate *Beyrichiana* Kellett is known from a single valve of one Permian species. Tentatively, it might be referred to the Hollinidae, but its proper classification must await further discoveries.

Family PRIMITIIDAE Ulrich and Bassler, 1923

Emended—Swartz, 1936

As has been stated in the previous discussion, it is here proposed to remove from the Primitiidae not only the eurychilinids, with their specialized frills and dimorphism, but also additional genera which show specialization along other lines of development. In other words, it seems desirable to adhere more rigorously to Ulrich and Bassler's concept of the family as "relatively simple Beyrichiacea with undefined to well defined median sulcus or simple submedian pit." With the arrangement here advocated, the family can be described as follows:

Small, straight-backed, unisulcate Ostracoda; frequently subrhomboidal, with the cardinal angles distinctly unequal; surface occasionally with inconspicuous swellings near the sulcus, and in part with inconspicuous rim or false border along the free edges, but never with strongly developed knobs, marginal ridge, or marginal frill. Hingement essentially simple, at least so far as known. Overlap wanting or inconspicuous; sexual dimorphism unknown.

The following genera are referred to the Primitiidae, and are illustrated on Plate 79.

Primitia Jones and Holl; Ordovician to Permian (?); genotype *Beyrichia mundula* Jones.

Primitiella Ulrich; Ordovician to Devonian; genotype *Primitiella constricta* Ulrich.

Haploprimitia Ulrich and Bassler; Ordovician to Devonian; genotype *Primitia minutissima* Ulrich.

Laccoprimitia Ulrich and Bassler; Ordovician, Silurian; genotype *Primitia centralis* Ulrich.

Euprimitia Ulrich and Bassler; Ordovician, Silurian; genotype *Primitia sanctipauli* Ulrich.

Halliella Ulrich; Ordovician to Devonian; genotype *Primitia? sculptilis* Ulrich (13).

Hallatia Kay; Ordovician; genotype *Hallatia healeyensis* Kay.

Pyxiprimitia Swartz, n. gen.; Devonian; genotype *Pyxiprimitia ventriclefta* Swartz, n. sp. (13).

Milleratia Swartz, n. gen.; Ordovician; genotype *Beyrichia cincinnatiensis* Miller.

The following additional genera are provisionally referred to this family:

Jonesites Coryell; Ordovician, Silurian; genotype *Placentula excavata* Jones and Holl.

Has weakly developed marginal and inner ridges which are somewhat suggestive of the Drepanellidae (13).

Hippa Barrande; Ordovician; genotype *Hippa latens* Barrande; includes two relatively simple, poorly known species.

Among the genera here included in the Primitiidae, sexual dimorphism is unknown, except in one Silurian species which has been placed in *Halliella*, namely, *Halliella fissurella* Ulrich and Bassler. The female of this species develops a strong subventral pouch. A similar pouch is seen in the European *Entomis inaequalis* Jones, which probably is the female of the associated *Primitia seminulum* Jones, referred to *Halliella* by Ulrich and Bassler. In the writer's opinion these species should be placed in a new genus, and included in the Kloedeninae.

The simplification of the Primitiidae, as here proposed, involves removal of a considerable number of genera included in the family by Ulrich and Bassler and by Bassler and Kellett. *Eurychilina* and its allies, including *Bolbibollia*, are referred to the Beyrichiidae. *Bollia*, *Jonesella*, and, provisionally, *Ulricha*, are placed in the new family Drepanellidae. *Aechmina* and *Paraechmina* are separated off as Aechminidae. *Acronotella*, *Monoceratina*, and *Mooreina* are placed in the family Acronotellidae, and *Primitiopsis* in the provisional family Primitiopsidae. Finally, *Bursulellela* Jones is best classed as a provisional member of the Leperditellidae (14).

EXPLANATION OF PLATE 79

Family PRIMITIIDAE (p. 549)

FIGS. *1*—*Primitiella* Ulrich, valve of genotype, *P. constricta* Ulrich, ×30, showing undefined mesial sinus. Ordovician, Decorah shale, Minneapolis, Minn.

2—*Haploprimitia* Ulrich and Bassler, valve of the genotype *H. minutissima* (Ulrich), ×60. Ordovician, Decorah shale, Fountain, Minn.

3a, b—*Euprimitia* Ulrich and Bassler, side view of valve and end view of carapace of the genotype, *E. sanctipauli* (Ulrich), ×30, showing simple sulcus, double border, and reticulate surface. Ordovician, Decorah shale, St. Paul, Minn.

4—*Laccoprimitia* Ulrich and Bassler, valve of genotype, *L. centralis* (Ulrich), ×30, showing border and pit-like sulcus. Ordovician, Trenton limestone, West Covington, Ky.

5a–i—*Primitia* Jones and Holl. *5a–d*, Side views, and sketches of dorsal and end outlines, of holotype of the genotype, *P. mundula* (Jones), ×30. The side view is probably a little tilted, causing the bulge in the dorsal margin. In *5b*, the background with its debris is removed. Photograph and sketches kindly furnished by T. H. Withers of the British Museum. Silurian, Scandinavian drift, near Berlin, Germany. *5e–g*, Side, end, and dorsal views of holotype of *P. bonnemii* Swartz, ×30. This species is close to the genotype, but the middle of the valve is broadly depressed. Silurian, near Mulde, Gotland. *5h i*, Side view of valve, and cross-section as from the right of *h*, of *P. tolli* Bonnema, ×18±, showing the hinge and marginal contacts as determined by Bonnema. Ordovician, Kuckers formation, Esthonia.

6a–e—*Milleratia* Swartz, exterior and interior of opposite valves, dorsal and end views of carapace, and vertical section of carapace of the genotype *M. cincinnatiensis* (Miller), ×37, showing asymmetrical dorsal umbos, and thickened free margin. Ordovician, Lorraine shales, Clarksville, Ohio.

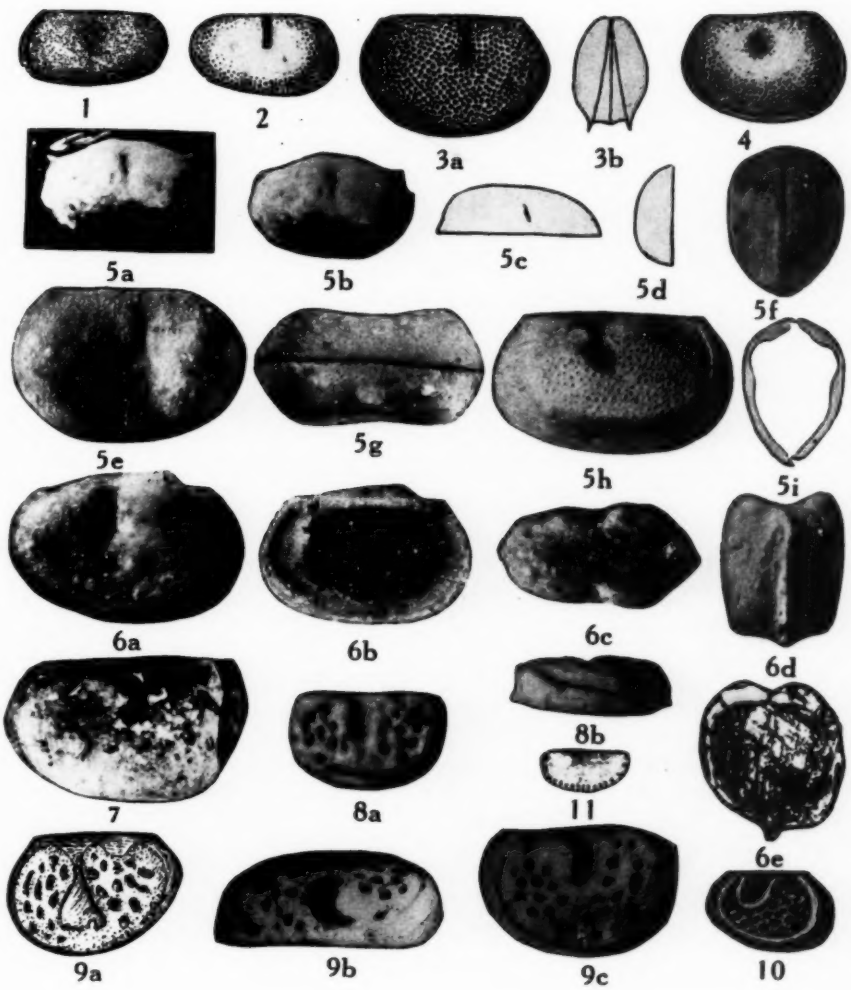
7—*Hallatia* Kay, valve of genotype, *H. healeyensis* Kay, ×30. Ordovician, Trenton group, Ontario.

8a, b—*Pyxiprimitia* Swartz, side and ventral views of valve of genotype, *P. ventriclefta* Swartz, ×30. Devonian, Shriver chert, Pennsylvania.

9a–c—*Halliella* Ulrich. *9a*, Valve of genotype, *H. sculptilis* (Ulrich), ×20. Ordovician, Trenton beds, Perryville, Ky. *9b, c*, Tilted dorsal and side views of valve of *H. magnapuncta* Kay, ×30. Ordovician, Decorah beds, Iowa.

10—*Jonesites* Coryell, valve of genotype, *J. excavatus* (Jones and Holl), enlarged. Silurian. England.

11—*Hippa* Barrande, valve of genotype, *H. latens* Barrande, ×10. Ordovician of Bohemia.



Swartz, Family Primitiidae

Family HOLLINIDAE Swartz, n. fam.

Straight-backed Ostracoda, primitively with one or two sulci, the intervening lobes regularly convex; later developing one or more rounded, sometimes irregularly arranged knobs; typically with a smooth or undulating frill, which usually parallels only a part of the free margin. In earlier forms, the hingement appears simple, overlap is wanting or inconspicuous, and dimorphism has not been recognized. In the Late Paleozoic *Hollinella*, however, hingement is provided by a tongue and groove arrangement, there is some overlap along the free margins, and the frill is subject to both age and sexual changes, although no beyrichiid pouch is developed.

The following genera are referred to this family, and are illustrated on Plate 80 (15):

Ctenobolbina Ulrich, Ordovician to Devonian; genotype *Beyrichia ciliata* Emmons.

Parabolbina Swartz, n. gen.; Devonian; genotype *Ctenobolbina granosa* Ulrich.

Hollina Ulrich and Bassler; Devonian, Mississippian; genotype *Ctenobolbina insolens* Ulrich.

Hollinella Coryell; Devonian to Permian; genotype *Hollinella dentata* Coryell.

Janischewskya Batalina; Carboniferous; genotype *Janischewskya digitata* Batalina.

Neochilina Matern; Devonian; genotype *Neochilina binsenbachensis* Matern.

The relations of some of the genera included in this family are not well assured. Ulrich and Bassler have suggested that *Hollina* is a derivative of *Treposella* of the Beyrichiidae, and not of *Ctenobolbina* (6*b*). According to this view the strong female pouch of *Treposella* has been lost by regressive evolution. The relationships of *Neochilina* are especially uncertain. *Neochilina* was included in the Eurychilininae by Matern and by Bassler and Kellett. It apparently lacks a female pouch, and the frill is not radially striate like the typical Beyrichiidae. It is Late Devonian in age, so that close relationship to the early non-dimorphic Beyrichiidae seems improbable. It may well prove to be a relative of *Hollina*, as here suggested (16).

Family TETRADELLIDAE Swartz, n. fam.

Subquadrate to suboval, straight-backed Ostracoda, the cardinal angles rather well marked, though more or less unequal; typically deeply sulcate, with subvertical ridges, but the ridges at times broken up into more or less irregularly arranged knobs; without a well defined marginal ridge or marginal frill. There is some tendency to develop an elliptical knob beside the median sulcus, and thus to suggest the Kloedeninae and Beyrichiidae. Hingement relatively simple, overlap wanting or inconspicuous. Female pouches, or other sexual dimorphism, unknown.

The following genera are referred to the Tetradellidae, and are illustrated on Plate 81:

Dilobella Ulrich; Ordovician; genotype *Dilobella typa* Ulrich.

Tetradella Ulrich; Ordovician; genotype *Beyrichia quadrilirata* Hall and Whitfield.

Ceratopsis Ulrich; Ordovician; genotype *Beyrichia chambersi* Miller.

Kiesowia Ulrich and Bassler; Ordovician; genotype *Beyrichia dissecta* Krause.

Thomasatia Kay; Ordovician; genotype *Thomasatia falcicosta* Kay (17).

Bassleratia Kay; Ordovician; genotype *Bassleratia typa* Kay.

Bellornatia Kay; Ordovician; genotype *Bellornatia tricollis* Kay.

Raymondatia Kay; Ordovician; genotype *Raymondatia goniglypta* Kay.

Tetradella appears to have developed out of *Dilobella* Ulrich, by development of secondary sulci on the elevated areas bordering the median sulcus. This is suggested not only by the similarity of the peculiar terminal loculi of *Dilobella fulcrata* (*Ctenobolbina fulcrata* Ulrich) (18) and of several species of *Tetradella*, but by the marked variation in strength and number of the secondary sulci in

species of the latter genus (Pl. 81, figs. 2*c*, *d*, *e*). The peculiar terminal loculi seen in these two genera may be dimorphic structures, although Kay states that all variations in strength of the buttresses are observed in *Tetradella ellipsilira*.

The lobation of *Ceratopsis* is so similar to that of *Tetradella* as to suggest close relationship, in spite of the dorso-terminal spine of the former. Ulrich and Bassler believe that the many knobs of *Kiesowia* were developed by breaking up the ribs of *Tetradella*.

The inclusion in the Tetradellidae of *Thomasatia*, *Bassleratia*, *Bellornatia*, and *Raymondatia*, is not well assured. However, close genetic relationship is suggested by such features as the shape of the carapace, and the general character of the lobation. *Dilobella*, *Ceratopsis*, *Tetradella*, *Thomasatia*, and *Bassleratia* all have a more or less well developed marginal flange, enclosing an elevated, variously sulcated and ribbed area, the three latter genera tending to develop a bulbous median lobe, which is also represented in *Raymondatia*.

Family Drepanellidae Swartz, n. fam.

Subquadrate to subovate Ostracoda, with long straight hinge, and subequal, generally well defined cardinal angles; usually with a strong ridge paralleling all or part of the free margins; primitively with swellings near the dorso-median sulcus, the swellings sometimes forming two or more strong knobs, which may connect ventrally to form a U-shaped ridge, or may become obsolete. Hingement apparently simple; marginal overlap wanting or inconspicuous.

The following genera are placed in the Drepanellidae, and are illustrated on Plate 82:

Drepanella Ulrich; Ordovician; genotype *Drepanella crassinoda* Ulrich.

Scofieldia Ulrich and Bassler; Ordovician; genotype *Drepanella bilateralis* Ulrich.

Explanation of Plate 80

Family Hollinidae (p. 551)

Figs. *1a–g*—*Ctenobolbina* Ulrich, showing wide variation in the degree of lobation in species now referred to this genus. *1a*, Valve of *C.*(?) *subcrassa* Ulrich, ×20. Ordovician, Stones River beds, High Bridge, Ky. *1b*, *c*, Side and end views of valve of *C. emaciata* (Ulrich), ×18. Ordovician, Maquoketa beds, Savannah, Ill. *1d*, Valve of genotype, *C. ciliata* (Emmons), ×15. Ordovician, Eden shale, Cincinnati, Ohio. *1e*, Valve of *C. punctata* Ulrich, ×18. Silurian, Rochester shale, New York. *1f*, *g*, Ventral and side views of valve of *C. papillosa* Ulrich, ×18, showing trend suggestive of *Hollina*. Devonian, Onondaga beds, Falls of the Ohio River, Louisville, Ky.

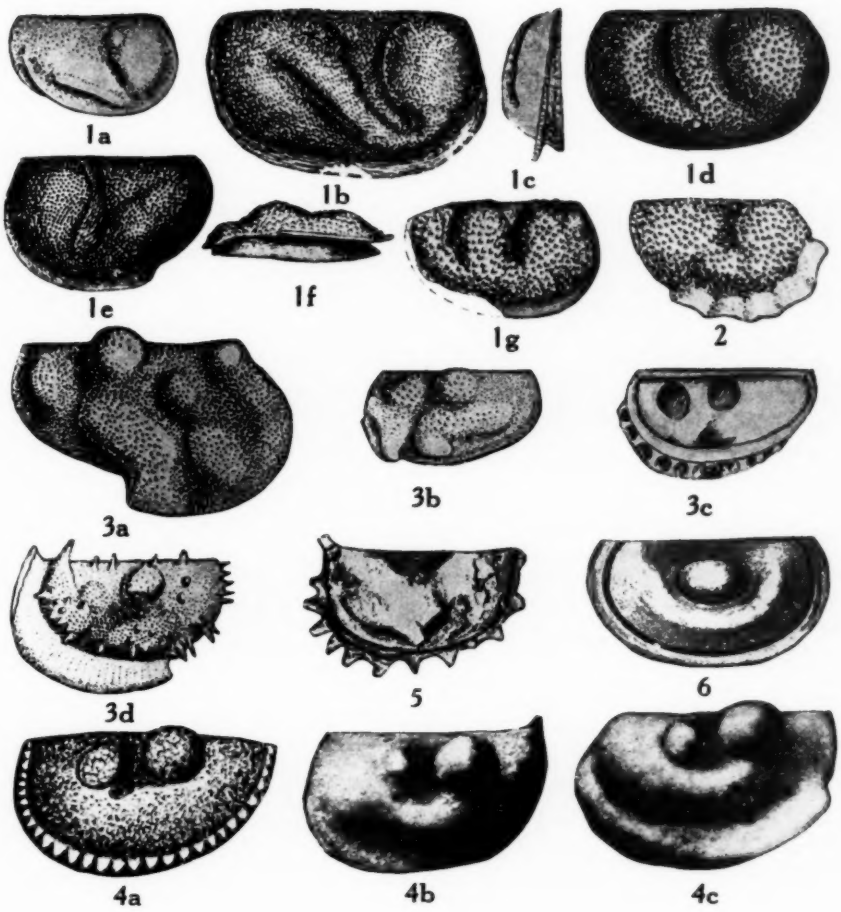
2—*Parabolbina* Swartz, valve of genotype, *P. granosa* (Ulrich), ×30. Devonian, New Scotland beds, Albany Co., N. Y.

3a–d—*Hollina* Ulrich and Bassler. *3a*, Valve of the genotype, *H. insolens* (Ulrich), ×25. Devonian, Onondaga beds, Falls of the Ohio River, Louisville, Ky. *3b*, Valve of *H. armata* Ulrich, ×17. Devonian, Onondaga beds, Falls of the Ohio River, Louisville, Ky. *3c*, Interior of valve of *H. cavimarginata* (Ulrich), ×18. The exterior is much like *H. armata*, and the loculi of the frill may be dimorphic structures. Devonian, Onondaga beds, Falls of the Ohio River, Louisville, Ky. *3d*, Valve of *H. spiculosa* (Ulrich), ×18. Devonian, Onondaga beds, Falls of the Ohio River, Louisville, Ky.

4a–c—*Hollinella* Coryell. *4a*, Valve of the genotype *H. dentata* Coryell, ×38. Pennsylvanian, Wewoka formation, Seminole Co., Okla. *4b*, *c*, Narrow and wide frilled valves of *H. gibbosa* Kellett, ×30. Kellett interprets these valves as representing non-productive and productive females, the male being frilless. Permian, Fort Riley and Emporia (?) limestones, Kan.

5—*Janischewskya* Batalina, valve of genotype, *J. digiata* Batalina, enlarged. Carbonifer ous of Novgorod, Russia.

6—*Neochilina* Matern, valve of genotype, *N. binsenbachensis* Matern, ×15. Upper Devonian, Binsenbach, Germany.



Swartz, Family Hollinidae

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Jonesella Ulrich; Ordovician, Silurian (?); genotype *Jonesella crepidiformis* Ulrich.

Bollia Jones and Holl; Ordovician to Devonian; genotype *Bollia bicollina* Jones and Holl.

The following additional genera are tentatively included in the family:

Ulrichia Jones; Devonian; genotype *Ulrichia conradi* Jones.

Polyzygia Gürich; Middle Devonian; genotype *Polyzygia symmetrica* Gürich.

In 1923, Ulrich and Bassler provisionally placed the Ordovician *Drepanella* and *Scofieldia* with the dimorphic Silurian *Drepanellina* and Devonian *Mesomphalus* in their subfamily Drepanellinae of the Zygobolbidae. They expressed some doubt about the naturalness of this association, because of the absence of brood pouches in the two Ordovician genera. It seems improbable to the writer that the subventral dimorphic pouches of *Drepanellina* and *Mesomphalus* were developed separately along any line of descent wholly independent of the Beyrichiidae. Accordingly, it is believed that the similarity in arrangement of the knobs and marginal ridges of *Drepanella crassinoda* and *Drepanellina clarki* is superficial, and not indicative of genetic relationship. *Drepanellina* and *Mesomphalus* are therefore referred to the Kloedeninae, and *Drepanella* and *Scofieldia* are removed from the Zygobolbidae.

It seems plausible to the writer that the early Stones River species *Drepanella elongata* represents the general stock from which the majority of the *Drepanellidae*, as here arranged, were developed. Strengthening of the dorsal swellings evidently led to such forms as *Drepanella crassinoda* and *Scofieldia bilateralis*. Reduction and obsolesence of these knobs apparently led to *Drepanella nitida* and *Jonesella pedigera*. Development of the yoke-like connection between the swellings led to *Drepanella bigeneris*, which seems to have all the characters of *Bollia*. The inner knobs of the typical species of *Ulrichia* are suggestive of the bulbous ends of the inner ridge of one section of *Bollia*. However, the strong sulcus of *Ulrichia affinis* suggests that *Ulrichia* may have developed independently out of some member of the Primitiidae, such as *Halliella* or *Jonesites*.

The genus *Ulrichia* especially needs revision. Reasons are given elsewhere for separation of certain Carboniferous species which evidently belong to the Kirkbyidae.

The relationships of *Polyzygia* are uncertain. This genus may be a derivative of *Bollia*, with a secondary ridge.

As has been pointed out by Ulrich and Bassler (5*f*), there is some resemblance between *Bollia* and the genera of their subfamily Zygobolbinae of the Zygobolbidae; but the latter group exhibits strong brood pouches, and generally possesses a small accessory third lobe which is never represented in *Bollia* nor in the other genera here referred to the Drepanellidae. Although dimorphism is unknown in the Drepanellidae in general, the form described in this paper as *Ulrichia terminata* may prove to be the dimorph of *U. pluripuncta*. No similar associated form could be found however, with the middle Shriver species *U. affinis*.

Family AECHMINIDAE Swartz, n. fam.

Subelliptical to subquadrate Ostracoda, with straight hinge and well marked subequal cardinal angles, and with a strong, remarkably persistent, dorso-median spine. Hingement appears simple; overlap inconspicuous or wanting. In part with a rounded pit adjacent to the spine; in part with marginal ridge or marginal spines.

The two following genera are included in the family, and are illustrated on Plate 83 (19):

Aechmina Jones and Holl; Ordovician to Devonian; genotype *Aechmina cuspidata* Jones and Holl.

Paraechmina Ulrich and Bassler; Silurian, Devonian; genotype *Aechmina spinosa* Hall.

Although this family is based on only two genera (28), there are many known species. Furthermore, the large hollow dorso-median spine is a striking and remarkably persistent feature, and so reflects a long-stable structural development.

The derivation of this family is uncertain. If the oldest described species of *Aechmina*, the non-pitted Richmond *A. richmondensis* Ulrich and Bassler, really represents the ancestral characters, the Aechminidae may have developed from some such genus as the umbonate *Schmidtella* (Pl. 83A, figs. 3*a*, *b*) of the Leperditellidae, and should not be considered members of the Beyrichiacea. However, possible relationship to the sulcate Black River species, *Dicranella* (?) *simplex* (Pl. 83A, figs. 4*a*, *b*), must also be given consideration.

Family Acronotellidae Swartz, n. fam.

Small straight-backed, generally unisulcate Ostracoda, with a strong laterally projecting spine or flange in the lower part of each valve. The posterior cardinal extremity tends to be extended, and there are sometimes anteriorly directed spines near the anterior cardinal angle. In early forms, the hingement appears to be simple, but in some later species the cardinal surfaces develop an interlocking groove and bar. Marginal overlap is wanting or inconspicuous. Dimorphism is unknown.

Explanation of Plate 81

Family Tetradellidae (p. 551)

Figs. *1a–e—Dilobella* Ulrich. The terminal buttresses and loculi in *1d* are similar to those in *Tetradella*, *2b*, *c*, *e*, and may have some dimorphic significance. *1a*, Valve of genotype, *D. typa* Ulrich, ×19. Ordovician, Black River beds, St. Paul, Minnesota. *1b*, *c*, Side and end views of valve of *D.* (*Ctenobolbina*) *crassa* (Ulrich), ×20. This species is considered a synonym of *D. typa* by G. M. Kay (personal communication), although in his description Ulrich was confident that they are distinct. Ordovician, Black River beds, St. Paul, Minn. *1d*, *e*, Side and dorsal views of *D. fulcrata* (Ulrich), ×20. Ordovician, Black River beds, St. Paul, Minn.

2a–h—Tetradella Ulrich. The wide variation in development of the secondary sulci is shown by *2a*, *c*, and *d; c* approaching *Dilobella* in this respect. A distinctly bulbous median lobe is shown in *2d* and *h*, and is suggestive of the median lobe of *Thomasatia* in *5a*. The constriction of the lobes in *2h* shows a trend toward *Kiesowia*, *3*. *2a*, Valve of *T. ellipsilira* Kay, ×40. Ordovician, Decorah beds, Iowa. *2b*, *c*, Figures of valves identified by Ulrich with the genotype, *T. quadrilirata* (Hall and Whitfield). The specimen represented by *2b* is considered by Kay to belong to his *T. ellipsilira*, while *2c* is presumably a variety or possibly a distinct species. The terminal loculi are not of specific value, according to Kay. He does not mention the possibility that they are dimorphic structures. Ordovician, Decorah shale, Minneapolis, Minn. *2d–g*. Side and ventral view of valves of *T. ulrichi* Kay ×35, 35, 20, 20. Figures *2f* and *g* were published by Ulrich under the name *T.* (*Strepula*) *lunatifera* (Ulrich). *2d*, *e*, Ordovician, Trenton beds, near Gamebridge, Ontario. *2f*, *g*, Trenton beds, Cannon Falls, Minn. *2h*, Valve of *T.* (?) *marchia* (Krause), ×10. Ordovician drift, northern Germany.

3—Keisowia Ulrich and Bassler, valve of genotype *K. dissecta* (Krause), ×10. Ordovician drift, northern Germany.

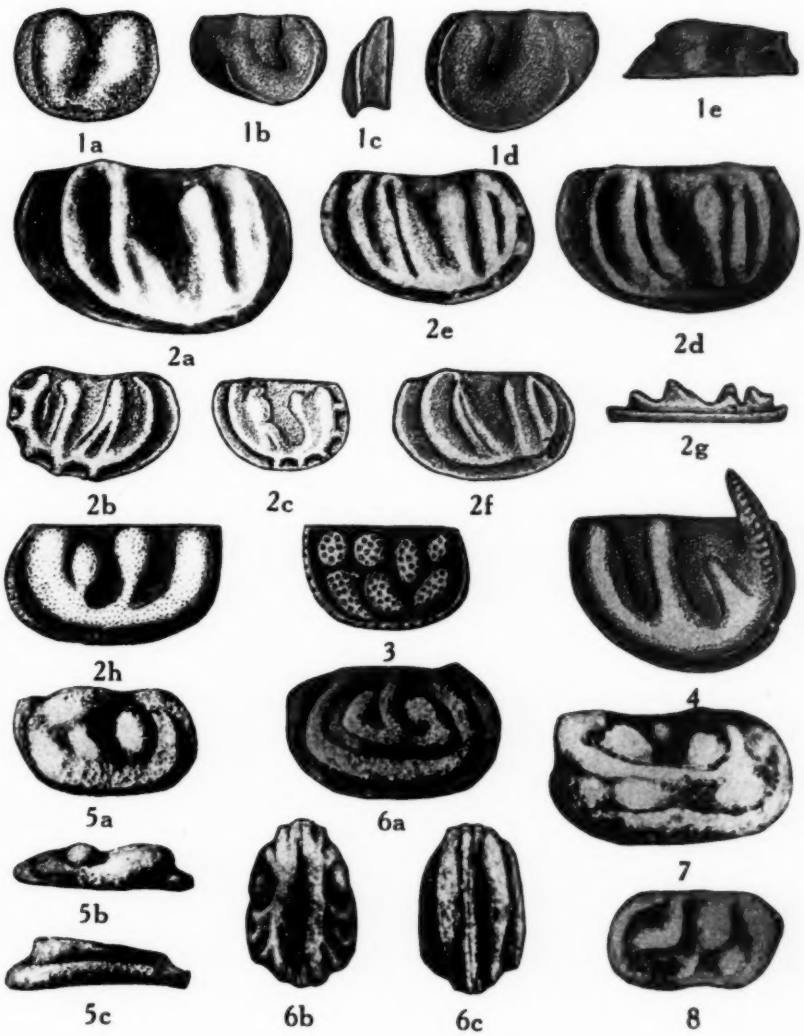
4—Ceratopsis Ulrich, valve of genotype *C. chambersi* (Miller), ×20. Ordovician, Decorah shale, St. Paul, Minn.

5a–c—Thomasatia Kay, side, dorsal, and ventral views of genotype, *T. falcicosta* Kay, ×30. Ordovician, Trenton beds, Healy Falls, Ontario.

6a–c—Bassleratia Kay, side view of valve, and dorsal and ventral views of a carapace of genotype, *B. typa* Kay, ×30. Ordovician, Trenton beds, Healy Falls, Ontario.

7—Bellornatia Kay, valve of genotype, *B. tricollis* Kay, ×50. Ordovician, Trenton beds, Ontario.

8—Raymondatia Kay, valve of genotype, *R. goniglypta* Kay, ×50. Ordovician, Trenton beds, Ontario.



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This family is proposed for the following genera, which are illustrated on Plate 83:

Acronotella Ulrich and Bassler; Ordovician to Devonian (?); genotype *Acronotella shideleri* Ulrich and Bassler.

Eoconchoecia Moberg; Silurian; genotype *Eoconchoecia mucronata* Moberg.

Monoceratina Roth; Devonian to Cretaceous (?); genotype *Monoceratina ventrale* Roth.

Mooreina Harlton; Pennsylvanian; genotype *Mooreina johnsvalleyensis* Harlton.

Acronotella was included in the Primitiidae by Ulrich and Bassler in 1923, and *Monoceratina* and *Mooreina* were also referred to this family by Bassler and Kellett in 1934. The straight hinge and simple dorso-median sulcus suggest relationship to *Primitia*, but the striking ventral spines or flanges represent a marked divergence from the simplicity of structure of that genus and its closer allies. Because of the persistence of the ventral projections in a considerable number of species, these structures seem to have considerable genetic significance. At the same time, the known species do not show any signs of intergradation between the Acronotellidae and the dorsally spined Aechminidae.

Monoceratina seems to be related to both the remaining Acronotellidae, on the one hand, and to the Cytheridae, on the other. Its affinities to the latter family have been strongly presented by C. I. Alexander, who cites "The presence of the compressed caudal process and the presence in some species of an anterior marginal rim . . . " A true "compressed caudal process" (Pl. 83B, fig. 3*c*) is not developed in the genotype, however (Pl. 83B, figs. 3*a*, *b*), and the straight hinge, dorso-median sulcus, and relatively rudimentary hingement favor the classification here used.

Family PRIMITIOPSIDAE Swartz, n. fam.

Straight-backed Ostracoda, in part with a small submedian pit; developing dimorphic terminal flanges, which may or may not meet to form a closed chamber. In part, at least, the one valve strongly overlaps the other along the free margins. Hingement apparently simple.

This family is provisionally proposed for the following genus, which is illustrated on Plate 83:

Primitiopsis Jones; Ordovician to Devonian; genotype *Primitiopsis planifrons* Jones.

The well marked dimorphic terminal flanges are fundamental structures which separate *Primitiopsis* from the Primitiidae, while the small submedian pit of *Primitiopsis planifrons* is not very suggestive of the dorso-median sulcus of *Primitia* and its allies.

The dimorphic structures of *Primitiopsis* are entirely different from the female pouches and swellings developed in the Beyrichiidae, Zygobolbidae, and Kloedenellidae, and from the variations of the frill of *Hollinella* described by Kellett. Thus they are not indicative of relationship with any of these groups, but must be regarded as entirely independent in origin.

Some nine species have been referred to *Primitiopsis*. It is evident, however, that such species as the non-pitted, non-reticulate, strongly inequivalved *P. oblonga* (Pl. 83C, figs. 3*a–f*) will have to be placed in a separate genus.

DIVISIONS OF THE BEYRICHIACEA

As has been pointed out, the order of discussion of the foregoing families is one of convenience, and is not meant to represent a biologic arrangement. Although not well understood, it seems desirable to attempt to outline the evolutionary relations of these and the other families currently included in the superfamily Beyrichiacea. It is probable that all of these groups, with the possible

exception of the Aechiminidae, were derived from early primitiid stocks. At the present time, it appears that the structural differences which were developed throw the Beyrichiacea into four more or less natural divisions, and these are outlined in the following paragraphs. In so far as these divisions are supported by further studies, it may prove desirable to regard them as superfamilies.

Superfamily BEYRICHIACEA

Straight-backed, more or less sulcate and lobate Ostracoda, derived from early Primitiidae.

Division of family PRIMITIIDAE

Straight-backed, more or less sulcate or lobate Ostracoda, lacking the subventral dimorphic pouches of the Beyrichiidae and Zygobolbidae, and the terminal dimorphic swellings of the Kloedenellidae; although other dimorphic structures are occasionally developed. In general, both dorsal angles are distinct. Apparently developed by radial evolution from early Primitiidae. Including the families: Primitiidae, Hollinidae, Tetradellidae, Drepanellidae, Acronotellidae, ?Primitiopsidae, ?Aechminidae (Leperditacea?).

Division of family BEYRICHIIDAE

Straight-backed, more or less sulcate and lobate Ostracoda; characterized, except in a few primitive genera, by subventral dimorphic pouches. In general, both dorsal angles are well defined. Apparently developed by evolution through early frilled but pouchless Beyrichiidae from early Primitiidae. Including the families: Beyrichiidae, Zygobolbidae.

Division of family KLOEDENELLIDAE

Straight-backed, more or less sulcate Ostracoda, elongate subrhomboidal in outline, the anterior cardinal angle rounded and inconspicuous. The early genera, at least, develop terminal di-

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EXPLANATION OF PLATE 82

Family DREPANELLIDAE (p. 552)

FIGS. *1a–f—Drepanella* Ulrich, showing wide variation in development of the lobation, tending: *1c*, toward *Scofieldia*, *1d*, toward *Jonesella*, and, *1f*, toward *Bollia*. *1a*, Valve of *D. elongata* (Ulrich), ×14. Ordovician, Stones River (?) beds, High Bridge, Ky. *1b*, Valve of *D. ampla* (Ulrich), ×14. Ordovician, Stones River (?) beds, High Bridge, Ky. *1c*, Valve of genotype, *D. crassinoda* (Ulrich), ×14. Ordovician, Black River beds, High Bridge, Ky. *1d, e*, Side view of valve and ventral view of carapace of *D. nitida* (Ulrich), ×14. Ordovician, Black River beds, High Bridge, Ky. *1f*, Valve of *D. bigeneris* Ulrich, ×15. This species probably should be placed in *Bollia*. Ordovician Decorah beds, Minneapolis, Minn.

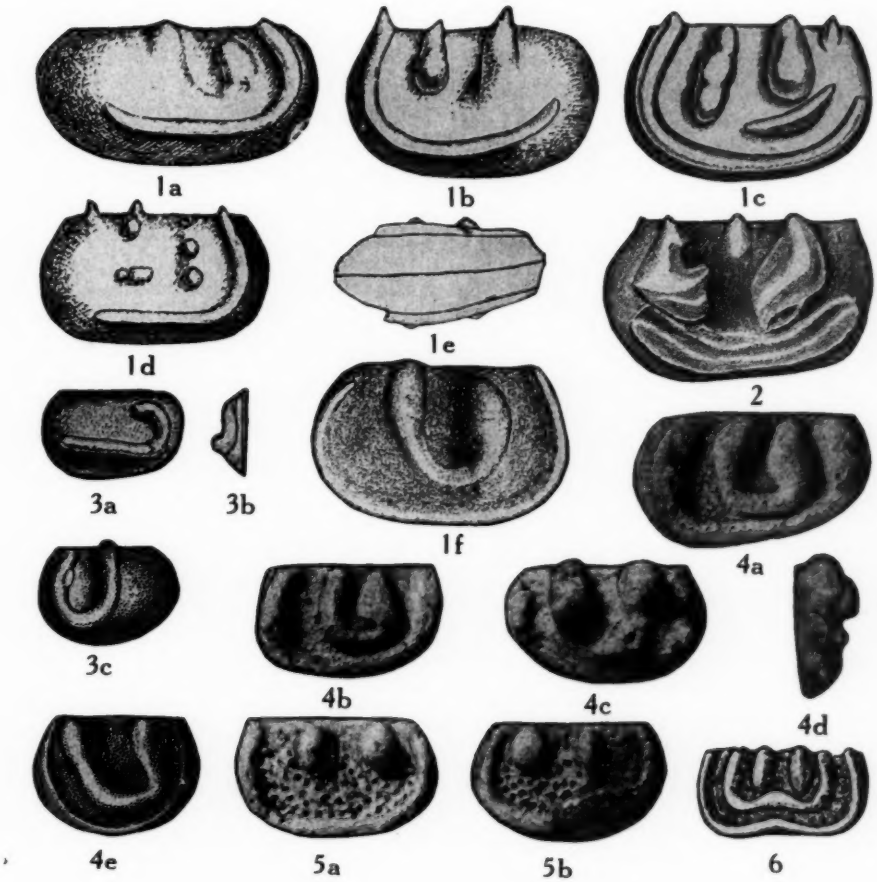
2—Scofieldia Ulrich and Bassler, valve of the genotype *S. bilateralis* (Ulrich), ×12. Ordovician, Decorah shale, St. Paul, Minn.

3a–c—Jonesella Ulrich. *3a, b*, Side and end views of valve of *J. pedigera* Ulrich, ×18, the ridge apparently corresponding to the submarginal ridge of *Drepanella*. Ordovician, Eden shales, Covington, Ky. *3c*, Valve of genotype *J. crepidformis* Ulrich, ×18. Ordovician, Eden shales, Covington, Ky.

4a–e—Bollia Jones and Holl. *4a, b*, Valves of *B. burgeneri* Swartz and *B. sagittaformis* Swartz, ×15, showing close similarity to *D. bigeneris*, *1f*. Lower Devonian, Shriver chert, Pa. *4c, d*, Side and end views of valve of *B. americana* var. *zygocornis* Swartz, n. var., ×15, Lower Devonian, Pa. *4e*, Valve of genotype, *B. bicollina* Jones and Holl, ×20. Silurian at Wenlock, England.

5a, b—Ulrichia Jones, valves of *U. pluripuncta* Swartz and *U. terminata* Swartz, ×30. The second may be dimorphid with the first. *U. pluripuncta* is very close to the genotype, *U. conradi* Jones, which was obtained from the Hamilton of Ontario. Lower Devonian, Shriver chert, Pa.

6—Polyzygia Gurich, valve of genotype, *P. symmetrica* Gurich, ×20. Middle Devonian, Poland.



Swartz, Family Drepanellidae

morphic swellings, quite distinct from pouches of the Beyrichiidae and Zygobolbidae. Possibly evolved from the primitiid stock represented by *Milleratia*. Including the families: Kloedenellidae, ?Glyptopleuridae.

Division of family KIRKBYIDAE

Straight-backed Ostracoda; in *Kirkbya* itself both dorsal angles are well defined; but in some other genera currently referred to the Kirkbyidae the outline is similar to that characteristic of the Kloedenellidae. In general, the sulci and lobes characteristic of the previous families are wanting; but a subcentral pit may be developed, and the surface is frequently reticulate, sometimes bearing knobs or ridges. Dimorphic pouches or swellings unknown. Later genera tend to develop specialized hinge structure. Including the families: Kirkbyidae, Youngiellidae.

ORIENTATION OF THE PRIMITIIDAE AND RELATED OSTRACODA

The antero-posterior orientation of Paleozoic Ostracoda is still a matter of discussion, with wide divergence of opinion concerning the significance of the available criteria. The question presents two more or less distinct aspects: first, what are the comparable ends of the carapace in different species, genera, and families; second, which is the anterior, which the posterior end of the carapace in terms of the animal which inhabited it?

In 1908 and 1923, Ulrich and Bassler concluded that, as shown by the presumably anterior position of the eye tubercles of *Leperditia*, and the supposedly posterior position of the female pouches of *Beyrichia* and related genera (Pl. 84, figs. 3*a–h*, 4*a–g*), the "swing" of the carapace in Paleozoic ostracodes is persistently backward, while the median sulcus, most important secondary sulcus, and median lobe, tend to lie behind the middle of the valve (5*g*) (6*c*). They also believed that these secondary criteria could be extended to orient Ostracoda in which eye tubercles and female swellings or pouches are unknown.

When applied only to the Beyrichiidae and Zygobolbidae, these criteria provide orientations which at first seem to be satisfactory. When extended to other groups, however, they produce interesting and disturbing anomalies. Thus Roth, using Ulrich and Bassler's criteria, oriented *Monoceratina* so that the specimen illustrated on Pl. 84, fig. 1 would represent a right valve. Alexander and others, on the contrary, working with related Mesozoic and Cenozoic ostracodes comparable to modern forms, consider this a left valve (20*a*). Similarly, Ulrich and Bassler oriented the Silurian Kloedenellidae by the swing and lobation, so that the specimens shown on Pl. 84, figs. 2*a–e* would represent right valves. As shown by the writer, however, the Silurian Kloedenellidae are persistently dimorphic, the swellings at the right hand end in the specimens shown on Pl. 84, figs. 2*b*, *d*, and at the lower end in 2*g*, being dimorphic, and not specific structures, as had been supposed by Ulrich and Bassler. Dimophic swellings also occur at this end of the carapace in the late Paleozoic, Mesozoic (?) kloedenellid genus *Jonesina* (Pl. 84, figs. 2*h–l*).

On the supposition that the swellings represent female incubation chambers and should be posterior in position, Ulrich and Bassler's orientation was reversed by the writer, and the specimens shown on Pl. 84, figs 2*a–e* are believed to be left valves (8*a*).

This orientation of the Kloedenellidae agrees with that used by Bonnema, whose "rules for orientation," as presented in 1934 (21), can be summarized as follows:

(1) The median sulcus marks the location of the adductor muscle, which is generally anterior in position in modern ostracodes. The median sulcus should therefore lie toward the front in fossil species.

(2) The knob-like median lobe of certain Primitiidae, Beyrichiidae, etc., lies in front of the median sulcus. In earlier

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EXPLANATION OF PLATE 83

A—Family AECHMINIDAE (p. 553)

FIGS. *1a–e—Aechmina*, Jones and Holl. *1a, b*, Side and end views of carapace of oldest described species, *A. richmondensis* Ulrich and Bassler, ×20. Ordovician, Richmond beds, Richmond, Ind. *1c*, Valve of genotype, *A. bovina* Jones, ×30; Silurian, Wenlock beds, England. *1d*, Valve of *A. cuspidata* Jones and Holl, ×20. Devonian, New Scotland limestone, Maryland, *1e*, Valve of *A. bigeneris* Swartz, ×25, with marginal spines of *Aechmina*, and dorsal pit (in shadow of dorsal spine) of *Paraechmina*. Lower Devonian, Shriver chert, Pa.

2—Paraechmina Ulrich and Bassler, valve of genotype, *P. spinosa* (Hall), ×20. Silurian, Rochester Shale, New York.

3a, b; 4a, b—Side and end views of the valves of *Schmidtella crassimarginata* Ulrich, ×10, and *Dicranella* (?) *simplex* Ulrich, ×20, illustrating possible origins of the Aechminidae. Ordovician, Black River limestone, Wisconsin, and Ordovician, Decorah shale, Minnesota, respectively.

B—Family ACRONOTELLIDAE (p. 554)

FIGS. *1a–c—Acronotella* Ulrich and Bassler, side, end, and dorsal views of carapace of genotype, *A. shideleri* Ulrich and Bassler, ×20. Ordovician, Richmond beds, Richmond, Ind.

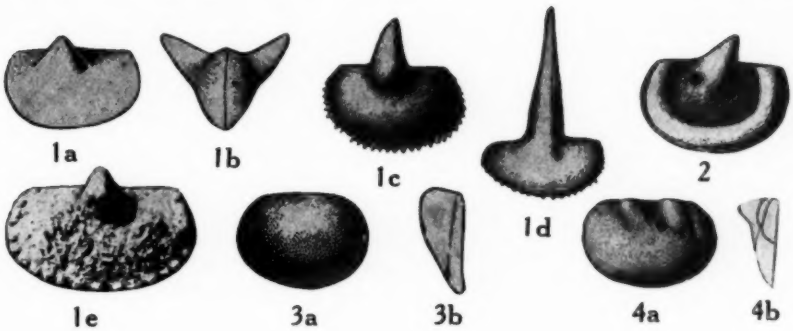
2—Eoconchoecia Moberg, valve of genotype *E. mucronata* Moberg. Silurian of Scania, Sweden.

3a–c—Monoceratina Roth. *3a, b*, Side and tilted ventral views of carapace of genotype, *M. ventrale* Roth, ×33. Pennsylvanian, Johns Valley shale, Okla. *3c*, Valve of *M. nitida* Alexander, ×56, showing caudal process and anterior rim characteristic of Mesozoic species assigned to this genus by Alexander. Cretaceous, Gober chalk, Texas.

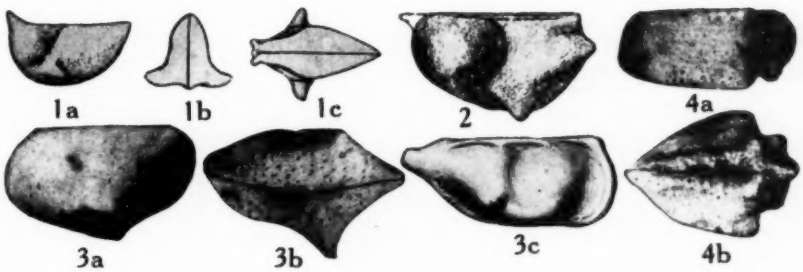
4a, b—Mooreina Harlton, side and dorsal views of genotype, *M. johnsvalleyensis* Harlton, ×50. Pennsylvanian, Johns Valley shale, Oklahoma.

C—Family PRIMITIOPSIDAE (p. 555)

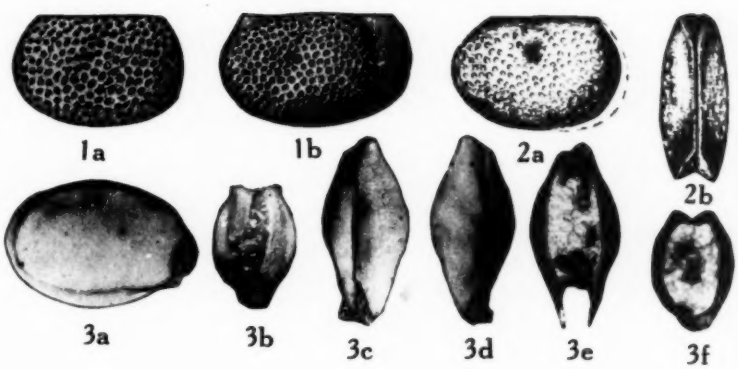
FIGS. *1a, b; 2a, b; 3a–f—Primitiopsis* Jones. *1a, b*, Male and female valves of the genotype, *P. planifrons* Jones, ×20, showing submedian pit and terminal female pouch. Silurian, Island of Gotland. *2a, b*, Side view of female valve with imperfect terminal flange, and dorsal view of female carapace of *P. bassleri* Harris, ×33. Ordovician, Tulip Creek and Bromide beds, Oklahoma. *3a–f*, Side, end, dorsal, and ventral views, and dorsal view of longitudinal section of female carapaces, and vertical section of male carapace, of *P. oblonga* (Jones and Holl), ×15±. *Beyrichia* drift of Vollenhove. These excellent and instructive photographs were made by J. H. Bonnema, and show the exterior characters, marginal overlap, and dimorphic terminal flanges of the female. In other longitudinal sections, Bonnema shows that the terminal flanges are more rudimentary in *P. reticristata* Jones and Holl, while they are larger, and bend to form a closed chamber in the carapace of *P. planifrons* Jones. Bonnema considers the flanges to be posterior in position in this genus, so that the right valve overlaps the left in *P. oblonga*.



A. Family Aechminidae



B. Family Acronotellidae



C. Provisional Family Primitopsidae

papers, this view was largely based on the supposition that the median knobs of *Primitia tolli* (Pl. 85, fig. 1*b*) represent the lateral eyes.

(3) The left valve generally overlaps the right in modern ostracodes. Bonnema considers this an important criterion for orientation of the Kloedenellidae, Beyrichiidae, and Primitiidae (Pl. 84, fig. 3*h;* Pl. 85, fig. 1*c*).

(4) The greatest height is generally in front of the middle.

(5) The female swellings of the Kloedenellidae indicate the posterior end; but, as shown by the preceding criteria, the pouches of *Beyrichia*, etc., are anterior in position.

(6) Hinge teeth, such as those of the Silurian Kloedenellidae, should be anterior in position, as is the case in *Ensis* and *Solen*.

Of the above rules, numbers 1, 3, and 6 support the orientation of the Kloedenellidae based upon the supposedly posterior position of the dimorphic swellings. Contrary to rule 4, however, the greatest height tends to be posterior to the middle. Furthermore, contrary to rule 3, the direction of overlap is reversed in the kloedenellid genus *Jonesina*, and several other Late Paleozoic genera.

As can be seen from the figures on Plates 84 and 85, the "swing" of the carapace, so much emphasized by Ulrich and Bassler, is dependent upon several factors, namely: (1) the relative protrusion of the cardinal angles, determined (a) by their relative sharpness, and (b) by the relative extension of the areas below the angles; and (2) the position of greatest height. In the Silurian Kloedenellidae, the recessive cardinal angle is constantly at the end opposite that bearing the dimorphic swellings, although the position of greatest height is variable. Furthermore, the median sulcus and most important secondary sulcus, together with the small intervening lobe, are always nearer the end with the recessive angle, while the greatest thickness seems to be uniformly nearer the end with the swellings. It is clear that, within the Kloedenellidae, the above features provide persistent and reliable data for comparative orientation.

Turning to the dimorphic Beyrichiidae and Zygobolbidae (Pl. 84, figs. 3*a–h*, 4*a–d*, 5*a–d*), examination shows that the more recessive cardinal angle and important secondary sulcus lie at one end of the carapace, generally with the greatest thickness toward the other. These features thus maintain, on the whole, the same relationships to one another observed in the Kloedenellidae, and provide reliable comparative orientations within the two families. A small bulbous median lobe is frequently developed, and always lies between the median sulcus and the recessive angle. The similar lobe of some Tetradellidae is also nearer the recessive angle (Pl. 85, figs. 3*a–e*). The median sulcus is variable in position, and in such bisulcate forms as *Beyrichia moodeyi* (Pl. 84, figs. 3*e*, *f*) is frequently nearer the end with the extended angle.

The persistence of intercorrelation in position of the recessive angle, important secondary sulcus, and greatest thickness within both the Kloedenellidae and the Beyrichiidae and Zygobolbidae, suggests that these features should provide com-

parative orientations between as well as within the two groups, and might be applicable to other families (Pl. 85). Unfortunately, their use places the dimorphic swellings at one end of the carapace in the Kloedenellidae, at the other end in the Beyrichiidae and Zygobolbidae, as can be seen on Pl. 84. This relationship accordingly throws doubt either on the value of the above features for comparative orientation, or else on the use of the dimorphic structures for both comparative and absolute antero-posterior orientation.

In his previous discussion of the

EXPLANATION OF PLATE 84

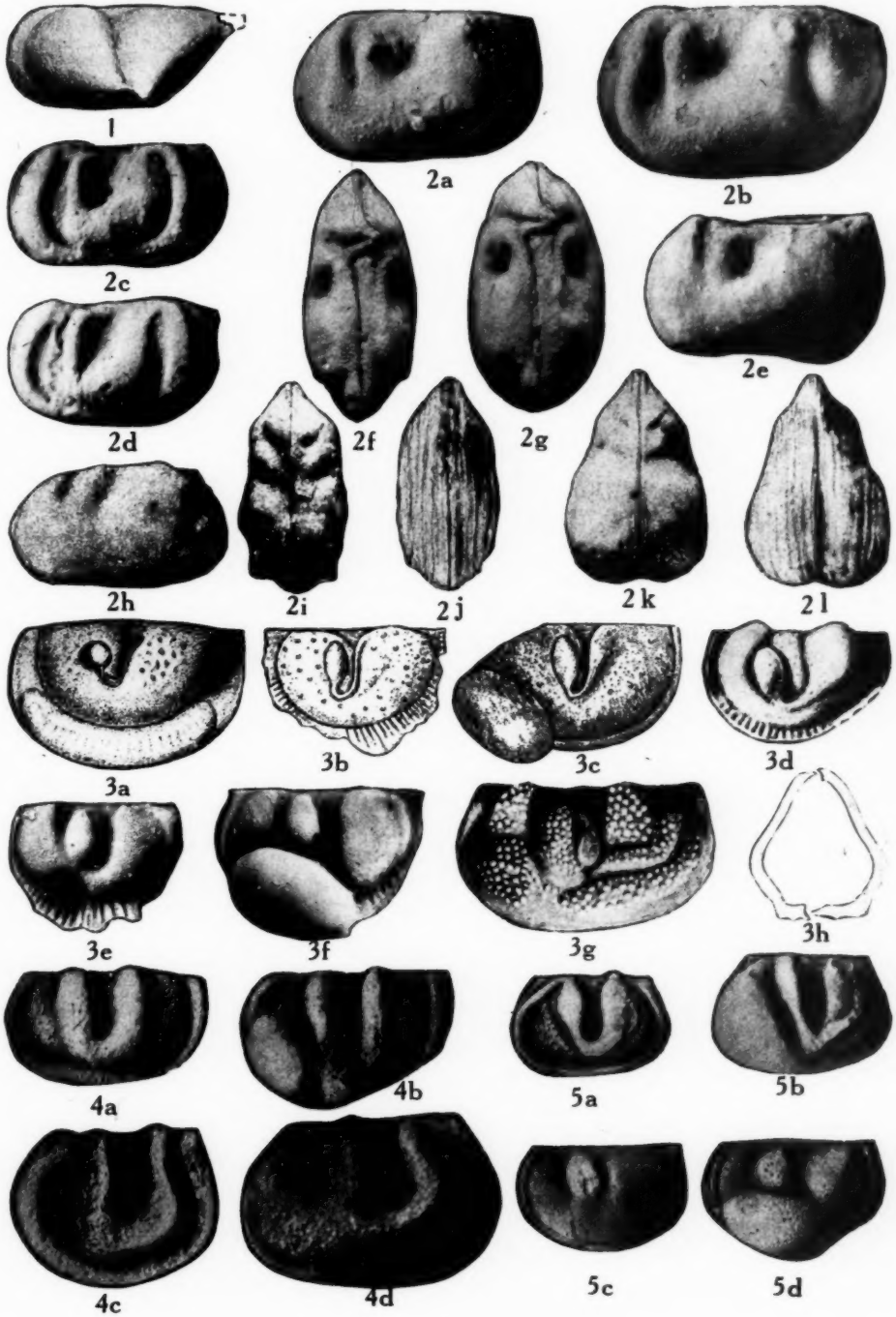
Orientation of ACRONOTELLIDAE, KLOEDENELLIDAE, BEYRICHIIDAE, and ZYGOBOLBIDAE

FIGS. *1*—Family ACRONOTELLIDAE. Side view of carapace of *Monoceratina parallela* Alexander, ×56, Cretaceous of Texas. This is the left side as oriented by Alexander by comparison with Mesozoic and Cenozoic Cytheridae. (p. 557)

2a–l—Family KLOEDENELLIDAE, *2a, b*, Male and female valves of *Kloedenella cornuta* (Ulrich and Bassler), ×30. *2c, d*, Male and female valves of *Dizygopleura conjugata* Swartz, ×30. *2e–g*, Side and dorsal views of male carapaces, and dorsal view of female carapace of *Kloedenella intermedia* (Ulrich and Bassler), ×30. *2h–l*, Side, dorsal, and ventral views of male carapace, and dorsal and ventral views of female carapace, of *Jonesina* (?) *minnekahtenis* Roth, ×35. The males were distinguished as *J. pahasapensis* by Roth (38). *2a–e, h*, are right valves as oriented by Ulrich and Bassler, but are left valves as oriented by the writer on the basis of the dimorphic pouches shown in *2b, d, g, k, l*, and as oriented by Bonnema on the basis of anterior position of the median sulcus and overlap by the left valve in the Silurian genera. The second orientation agrees better with that used by Alexander by *Monoceratina*. Note the persistent intercorrelation in position of the recessive angle, median and secondary sulcus, and the dimorphic swellings, while the greatest height is variable in position. The thicker end of the males corresponds to the end with the dimorphic swellings in the females. In *2a*, the lobe between the two sulci is somewhat suggestive of the knob-like median lobe of the Beyrichiidae, *3a–g*. (p. 557)

3a–h—Family BEYRICHIIDAE. *3a*, Female (?) valve of *Eurychilina ventrosa* Ulrich, ×14. Ordovician, Minnesota. *3b, c*, Male and female valves of *Craspedobolbina dietrichi* Kummerow, ×25. Ordovician drift of Germany. *3d*, Male valve of *Beyrichia clavata* Kolmodin, ×12±. Silurian of Europe. *3e, f*, Male and female valves of *Beyrichia moodeyi* Ulrich and Bassler, ×15. Silurian of Pennsylvania. *3g, h*, Male valve, and vertical section of male carapace as from right end of *3g*, of *Beyrichia tuberculata* (Klöden), ×10, 12. *3c, f*, are reversed figures to show comparative relations. Note that recessive angle, secondary sulcus, and median lobe are persistently intercorrelated, and always lie toward the one end of the carapace. The greatest thickness is rather persistently near the other end of the carapace, while the position of greatest height is variable, and the median sulcus tends to shift position when one secondary sulcus is developed. *3a–g* are all right valves, as oriented by Ulrich and Bassler, but are left valves as oriented by Bonnema. The second orientation agrees better with the writer's orientation of the Kloedenellidae, and Alexander's orientation of *Monoceratina*, judging from the positions of the recessive angle and the secondary sulcus. (p. 559)

4a–d; 5a–d—Family ZYGOBOLBIDAE. *4a–d*. Subfamily ZYGOBOLBINAE. *5a–d*. Subfamily KLOEDENINAE. *4a, b*, Male and female valves of *Zygobolbina conradi* var. *latimarginata* Ulrich and Bassler, ×8. Silurian of Georgia and Maryland. *4c, d*, Male and female valves of *Bonnemaia rudis* Ulrich and Bassler, ×8. Silurian of Tennessee. *5a, b*, Male and female valves of *Mastigobolbina triplicata* (Foerste), ×8. Silurian of Pennsylvania. *5c, d*, Male and female valves of *Kloedenia normalis* Ulrich and Bassler, ×12. Silurian of Maryland. As shown by the recessive angle, median knob, and subventral female pouches, these valves all correspond to those used to illustrate the Beyrichiidae. They are right valves according to Ulrich and Bassler and left valves according to Bonnema. As in the Beyrichiidae, the median lobe and female pouches always lie near the end with the recessive angle, while the greatest thickness is persistently nearer the other end of the carapace. (p. 559)



Swartz, Orientation of Acronotellidae, Kloedenellidae, Beyrichidae, and Zygobolbidae

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Kloedenellidae, the writer called attention to the fundamental differences both in outline of the carapace and position and character of the female swellings in the Kloedenellidae, on the one hand, and the Beyrichiidae, on the other. It was concluded that the criteria afforded by lobation and shape could not be used with assurance in the comparative orientation of the two groups, and that in both groups the supposed posterior position of the dimorphic swellings and pouches provides the most reliable known evidence for determining the relation of the carapace to the animal which inhabited it.

At the present time the writer is more impressed by the persistence in intercorrelation of position of the recessive angle, important secondary sulcus, greatest thickness, and, where developed, bulbous median lobe, and is inclined to place greater value upon these features for comparative orientations. Furthermore, the dimorphic swellings of the Kloedenellidae correspond better in their general character and terminal position to the incubation chambers found in the posterior part of the carapace of females of some modern ostracodes, than do the swollen subventral pouches of the Beyrichiidae and Zygobolbidae. Their supposedly posterior position is also in accord with the evidence afforded by the recessive angle, which seems to be persistently anterior in position in the more or less straight-backed Mesozoic and Cenozoic ostracodes comparable in outline to *Monoceratina* (22). In view of these relationships, and since the subventral pouches of the Beyrichiidae seem to have developed out of the frill, as is suggested by *Eurychilina ventrosa* and *Beyrichia moodeyi*, it is possible that these pouches are antero-ventral rather than postero-ventral in position. An anterior position for the nearly terminal pouch *Mastigobolbina* (Pl. 84, fig. 5*b*) is very remarkable, but would be demanded by the above orientation of the Beyrichiidae.

It is unfortunate that orientation is not only an interesting philosophical problem, but also a descriptive requirement. In the present paper, statements involving orientation have been omitted in the discussions of the Beyrichiidae, Primitiidae, and related families, and the explanation of the accompanying figures, although some data for comparative orientations of these families are presented on Plates 84 and 85. The orientations used in the following descriptions of new species are based on comparisons with the Kloedenellidae, with emphasis upon the supposed anterior position of the recessive angle and, in unisulcate genera, of the median sulcus. They are not always satisfactory, especially in the case of *Ulrichia* and *Bollia*, and it seems to the writer that neither comparative nor absolute orientation of the straight-backed Paleozoic ostracodes can be considered firmly established at the present time.

The most conclusive data for orientation would, of course, be provided by discovery of specimens preserving parts of the appendages,

and particularly of the abdomen, as in the Carboniferous specimen of *Paleocypris edwardsi* illustrated by Brongniart (5*h*). The writer has made sections of complete carapaces of Silurian Kloedenellidae for this purpose, but without success. Further investigations, particularly with more robust forms, would be worth while, even though results are unlikely. Specimens in black shales might provide especially promising material.

LIST OF SPECIES

The species described in this paper are listed below (1) (2). Unless otherwise noted, the specimens were obtained in the Lower Devonian Shriver chert of central Pennsylvania. The new genera, *Paraschmidtella*, *Milleratia Pyxiprimitia*, *Parabolbina*, *Tubulibairdia*, and *Kellettina*, are proposed, the last being described in a footnote on page 585.

The types of the new species ex-

EXPLANATION OF PLATE 85

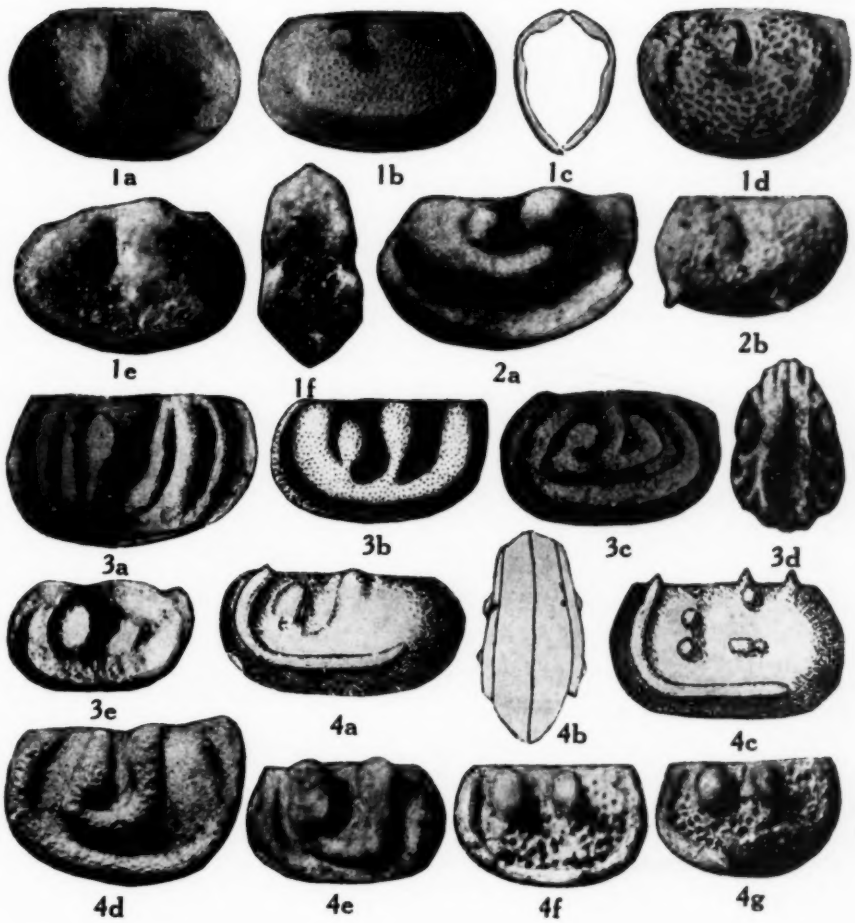
Orientation of the PRIMITIIDAE, HOLLINIDAE, TETRADELLIDAE, and DREPANELLIDAE

FIGS. *1a–f*—Family PRIMITIIDAE, Ulrich and Bassler. *1a*, Side view of carapace of *Primitia bonnemai* Swartz, ×30, reversed to show comparative orientation. Silurian of Gotland. *1b, c*, Side view of valve, and vertical section of carapace (as from right end of *1b*) of *Primitia tolli* Bonnema, ×17. Ordovician of Esthonia. *1d*, Valve of *Halliella labrosa* Ulrich, ×30. Ordovician of Minnesota. *1e, f*, Side view of valve and dorsal view of carapace (as with left end of *1e* at top) of *Milleratia cincinnatiensis* (Miller), ×37. Ordovician of Ohio. The side views represent right valves according to Ulrich and Bassler's orientations, left according to Bonnema's. Comparison with the Kloedenellidae (Pl. 84, figs. *2a–l*), favors Bonnema's orientation, in the writer's opinion. According to this orientation, the top end of *2l* and *2f* is anterior. (p. 559)

2a, b—Family HOLLINIDAE Swartz, *2a*, Valve of productive female of *Hollinella gibbosa* Kellett, ×30. Permian of Kansas. *2b*, Valve of *Parabolbina ventrispinosa* Swartz, ×30. Devonian of Pennsylvania. The positions of the recessive angle and median sulcus indicate that these valves correspond to those shown in *1a, b, d, e*. Note the shift in position of greatest height. (p. 559)

3a–e—Family TETRADELLIDAE Swartz. *3a*, Valve of *Tetradella ulrichi* Kay, ×35. Ordovician, Ontario. *3b*, Valve of *Tetradella marchia* (Krause), ×10. Ordovician drift, Germany. *3c, d*, Side view of valve, and dorsal view of carapace of *Bassleratia typa* Kay, ×30. Ordovician, Ontario. *3e*, Valve of *Thomasatia falcicosta* Kay, ×30. Ordovician, Ontario. Figures *3a* and *c* are reversed to show comparative orientation. The positions of the recessive angle, and of greatest thickness as shown in *3d*, indicate that these valves correspond to those shown in *1a–e*. Also note that the bulbous median lobe is constantly between the median sulcus and the recessive angle, as in the Beyrichiidae. (Pl. 84 figs, *3a–g*). Comparison with the Primitiidae, and thus with the Kloedenellidae, suggests that these are left valves. (p. 559)

4a–g—Family DREPANELLIDAE Swartz. *4a*, Valve of *Drepanella elongata* Ulrich, ×11. Ordovician, Kentucky. *4b, c*, Ventral view of carapace, and side view of valve of *Drepanella nitida* (Ulrich), ×14. Ordovician, Kentucky. *4d*, Valve of *Bollia burgeneri* Swartz, ×15. Devonian, Pennsylvania. *4e*, Valve of *Bollia americana* var. *zygocornis* Swartz, ×15. Devonian, Pennsylvania. *4f, g*, Valves of *Ulrichia pluripuncta* Swartz and *U. terminata* Swartz, ×15. Devonian, Pennsylvania. *4a* and *c* are reversed to show comparative orientations. In *4a* and *c* there is little difference in the dorsal angles, but the position of the median sulcus and position of greatest thickness, as shown in *4b*, indicate that these valves correspond to those shown in *1a–e*, *2a,b* and *3a–e*. The valves shown in *4d–g* apparently correspond to one another and to the other valves shown in the figure, judging from the position of the recessive angle in *1d, f*, and *g*, and the position of the more important of the two knobs. Thus these appear to be left valves according to Bonnema's orientations, and according to the writer's orientation of the Kloedenellidae. (p. 559)



Swartz, Orientation of Primitiidae, Hollinidae, Tetradellidae, and Drepanellidae

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cept *Primitia bonnemai* are deposited in the U. S. National Museum.

Paraschmidtella dorsopunctata Swartz, n. sp.
Aechmina bigeneris Swartz, n. sp.
Aechmina spinoterminata Swartz, n. sp.
Primitia mundula (Jones), Silurian drift, Germany.
Primitia bonnemai Swartz, n. sp., Silurian, Gotland.
Milleratia cincinnatiensis (Miller), Ordovician, Ohio.
Primitiella (?) *ventricosa* Swartz, n. sp.
Pyxiprimitia ventriclefta Swartz, n. sp.
Pyxiprimitia ventripunctata Swartz, n. sp.
Parabolbina limbata Swartz, n. sp.
Parabolbina ventrispinosa Swartz, n. sp.
Bollia sagittaformis Swartz, n. sp.
Bollia burgeneri Swartz, n. sp.
Bollia americana var. *zygocornis* Swartz, n. var.
Bollia cristata Swartz, n. sp.
Bollia ungula Jones, Middle Devonian, Pennsylvania.
Ulrichia affinis Bassler and Kellett.
Ulrichia pluripuncta Swartz, n. sp.
Ulrichia terminata Swartz, n. sp.
Acanthoscapha pentagonalis Swartz, n. sp.
Tubulibairdia tubulifera Swartz, n. sp.
Parahealdia (?) *centralis* Swartz, n. sp.
Cavellina paraquaesita Swartz, n. sp.

SYSTEMATIC DESCRIPTIONS

Family LEPERDITELLIDAE Ulrich and Bassler

Genus PARASCHMIDTELLA Swartz, n. gen.

Genotype: *P. dorsopunctata* Swartz, n. sp.

Small, straight-hinged, elliptical to subquadrate Ostracoda, with broad thickened dorsal umbos, which generally project beyond the hinge, and thus modify the dorsal margin. Surface marked by deep, distant, rounded puncta. Hingement and overlap not well known.

Relationships. The species placed in this genus are close to *Schmidtella* Ulrich, but differ from *S. crassimarginata*, the type of that genus, in the absence of the broad flattened margin, and the presence of the deep puncta. In addition to *P. dorsopunctata*, the following species should be placed in *Paraschmidtella: Aparchites perforata* Harris (23), *Aparchites variolatus* Ulrich and Bassler, (5*i*) and *Eridoconcha rotunda* Ulrich and Bassler (5*j*). *Aparchites* Jones should include non-umbonate species, most convex ventrally, with smooth surface and thickened edges. *Eridoconcha* Ulrich and Bassler was proposed for species with pointed umbos and concentric bands suggestive of growth lines.

P. perforata is equivalved, according to Harris, with a shallow groove in the hinge of the left (?) valve, into which fits the beveled edge of the other valve. Hingement and overlap are unknown in the other species placed in the genus.

PARASCHMIDTELLA DORSOPUNCTATA Swartz, n. sp.

Plate 86, figures 1*a–c*

Carapace longitudinally subelliptical to subquadrate in side view. Hinge straight, about four-fifths the greatest length, but outline of dorsal margin somewhat modified by protrusion of the broad dorsal umbos; other margins more or less regularly rounded. Cardinal angles obtuse, best seen in internal casts. Hingement apparently simple, judging from the internal molds; overlap not observed.

Surface of valve strongly convex, greatest convexity a little above and behind the middle; ventral part of surface sloping gently and regularly to the ventral and lateral margins; dorsal part of valve swollen, forming a broad elevated umbo. Areas near the cardinal angles, particularly to the posterior angle, somewhat flattened. Dorsal two-thirds of the surface of the valve marked by about thirty widely spaced, small, rounded, rather deep puncta, generally somewhat variable in size and irregular in arrangement.

Natural internal casts show a distinct furrow a little in front of the middle of

the dorsal half, representing a low vertical internal ridge which is not reflected on the exterior surface of the valve. This ridge probably served for attachment of the adductor muscle. The strong external puncta scarcely show on most of the internal casts, indicating that the carapace is very thin at the floors of the puncta.

Length 0.8 mm., height 0.6 mm., convexity of valve 0.28 mm.

Relationships.—There are some small associated specimens which may represent immature individuals, although the puncta are not restricted to the dorsal part of the surface. *P. dorsopunctata* is very close in appearance to *P. perforata* (*Aparchites perforata* Harris), but in the latter species the puncta occur in the ventral as well as the dorsal parts of the valve.

Occurrence.—Fairly common in *Metaplasia plicata* zone of middle part, rare in upper part, of the Shriver chert, Curtin, Pa.; rare 90–110 feet above base of Shriver, Hollidaysburg, Pa.

Family AECHMINIDAE Swartz

Genus AECHMINA Jones and Holl

AECHMINA BIGENERIS Swartz, n. sp.

Plate 86, figures 2*a*, *b*

Carapace, without the dorsal spine, elongate subelliptical in side view; dorsal margin straight, hingeline about three-fourths the greatest length; ventral margin moderately convex; anterior and posterior margins more or less regularly rounded, about equally protruberant; cardinal angles obtuse. Hingement and overlap not observed.

Surface of valve depressed convex; sharply deflected near the free margins. The summit of the angulation thus produced is set with about eighteen small spines, the spines becoming obsolete near the cardinal angles. Only the bases of these spines are shown in the photographs. The dorso-median spine is large, broad-based, situated well up toward the dorsal margin, and is about equidistant from the ends of the valve. It apparently projects upward and outward at an angle to about forty-five degrees to the plane between the two valves. The spine is incomplete in the specimen figured, and its length and the character of its terminus are uncertain. There is a small, rather shallow, not well defined pit, postventral to the base of the spine. Just behind and a little below the pit the surface rises into a low undefined rounded swelling; and behind this low swelling, near to and paralleling the dorsal third of the posterior margin, is a sharply elevated, short, abruptly terminated ridge; its summit set with two or three low spines or nodes, similar to those paralleling the free margins. Surface apparently without other ornamentation.

The dimensions of the one complete valve are: length 1.25 mm., height, without large spine, 0.66 mm., convexity 0.20 mm., height of the short posterior ridge 0.06 mm.

Relationships.—*Aechmina bigeneris* has the pit of *Parachemina*, together with the marginal spines common in *Aechmina*. It lacks the marginal ridge of typical species of *Paraechmina*, although the peculiar post-dorsal elevation might be considered a remnant of this structure. The next described *A. spinoterminata* is the most closely related known species.

Occurrence.—Two specimens were found in the *Metaplasia plicata* zone of the middle part of the Shriver chert, Curtin, Pa.

AECHMINA SPINOTERMINATA Swartz, n. sp.

Plate 86, figures 3*a–d*

Carapace, without the large dorsal spine, subelliptical in side view; dorsal margin straight, hingeline about three-quarters of the greatest length; ventral margin gently convex; ends more or less regularly rounded, about equal; cardinal angles about equally obtuse. Hingement and overlap not observed.

Surface of valve gently convex, greatest convexity behind the middle; sharply

deflected near the anterior and posterior margins, the deflection less well marked along the ventral margin. The angulations parallel to the anterior and posterior margins each set with about ten minute spines or nodes, the spines apparently being restricted to the ends of the valve and absent along the ventral margin. Large dorso-median spine broad-based, fairly long, bent slightly toward the front, inclined at an angle of about forty-five degrees to the plane between the two valves; its length and the character of its terminus uncertain from the specimens seen. The base of the spine is well up toward the dorsal margin, and is about equidistant from the ends of the valve. The pit behind and below the base of the spine is fairly well defined, moderately deep. Behind and below the pit the surface rises into a low undefined rounded swelling, its diameter a little greater than that of the pit. Above the pit and swelling the surface lowers gently into a broad shallow depression; bordered anteriorly by the base of the large spine, posteriorly by a low rounded hump.

In the smaller of the two observed specimens, the surface appears to be devoid of further ornamentation. In the larger specimen, however, the area behind the pit is set with rather widely spaced minute very low rounded pustules, about 0.04 mm. in diameter. These pustules appear to be absent elsewhere on the valve, although preservation seems equally good.

Dimensions of the larger valve are: length 1.64 mm., height 0.96 mm., convexity 0.29 mm., greatest height of the marginal deflected area 0.10 mm.

Relationships.—This species resembles *Aechmina bigeneris* in size, outline, convexity, the position and character of the large dorsal spine, the low rounded swelling behind the pit, and in the presence of small submarginal spines. However, the peculiar posterior ridge of that species is absent, the submarginal spines are much smaller, and they are confined to the ends of the valve, being absent along the ventral margin.

Occurrence.—Two specimens were found in an horizon about two-thirds above the base of the Shriver chert on the east side of Pine Creek, between Avis and Jersey Shore, Pa.

Family PRIMITIIDAE Ulrich and Bassler

Genus PRIMITIA Jones and Holl

PRIMITIA MUNDULA (Jones)

Plate 86, figures 4*a–c*

Beyrichia mundula JONES, *1885*, Ann. Mag. Nat. Hist., ser. 2, vol. 16, p. 90, pl. 5, fig. 23. For further bibliography see BASSLER, R. S. and KELLETT, BETTY, Bibliographic Index of Paleozoic Ostracoda: *Geol. Soc. Am., Special Papers*, no. 1, p. 449, 1934. Most of the specimens which have been identified as *P. mundula* will probably have to be placed elsewhere.

Some years ago the writer examined specimens from the Silurian drift of Germany, provisionally identified as *Primatia mundula*, the genotype of *Primitia*, by Krause, and deposited in the U. S. National Museum at Washington (U.S.N.M. 82414). Among these specimens is a well preserved carapace, which is strongly inequivalved and has a very weak sulcus (Pl. 86, figs. 5*a–c*). It was obvious that if this specimen really represents *P. mundula*, the characters of *Primitia* and thus of the family Primitiidae have been misunderstood. Entirely different characters are exhibited by the umbonate *Beyrichia cincinnatiensis* Miller, figured by Ulrich and Bassler as a typical American example of *Primitia* (Pl. 86, figs. 7*a–c*). In order to obtain further light on the problem, the writer wrote to J. H. Bonnema, who kindly loaned Gotland specimens provisionally identified as *P. mundula* (Pl. 86, figs. 6*a–g*), and who suggested that Jones' type might be at the British Museum. T. H. Withers of the British Museum subsequently furnished a photograph and edge view drawings of the holotype, No. I. 6880, which has "fig. 23" written beside it in Jones' handwriting. Dr. Withers states that the

dorsal angles are incomplete (Pl. 86, fig. 4*a*), that there are no dorsal humps such as those of *Milleratia cincinnatiensis* (Pl. 86, figs. 7*a–e*), and that no data concerning marginal overlap and hingement can be obtained from the specimens.

The holotype measures about as follows: length 0.70 mm., height 0.47 mm., convexity 0.2 mm.

Occurrence.—Jones' "No. 1 limestone," or specimen No. 1, from the Scandinavian limestone drift of Berlin, Germany.

PRIMITIA BONNEMAI
Swartz, n. sp.

Plate 86, figures 6*a–g*

Carapace strongly biconvex, suboblong in dorsal view; ovoid in end view, the dorsal margin broadly rounded, the greatest thickness above the middle; subovoid in side view, the dorsal margin straight, but only two-thirds to three-fourths the greatest length. As here oriented, the anterior cardinal angle is more obtuse than the other, the anterior

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EXPLANATION OF PLATE 86

FIGS. *1a–c—Paraschmidtella dorsopunctata* Swartz, n. gen. and n. sp., squeeze from external mold, and side and posterior views of natural internal mold of the holotype, a left valve, ×30. The cardinal angles are imperfect in *1a*. Note the impression of the internal ridge in *1b*, and the dorsal umbo in *1c*. *M. plicata* zone, middle part of Shriver chert, Curtin, near Bellefonte, Pa. (p. 563)

2a, b—Aechmina bigeneris Swartz, n. sp., side and ventral views of squeeze from the holotype, an external mold of a left valve, ×30, showing bases of the marginal spines, and the short posterior ridge. The tip of the dorso-median spine is imperfect. *M. plicata* zone, middle part of Shriver chert, Curtin, near Bellefonte, Pa. (p. 564)

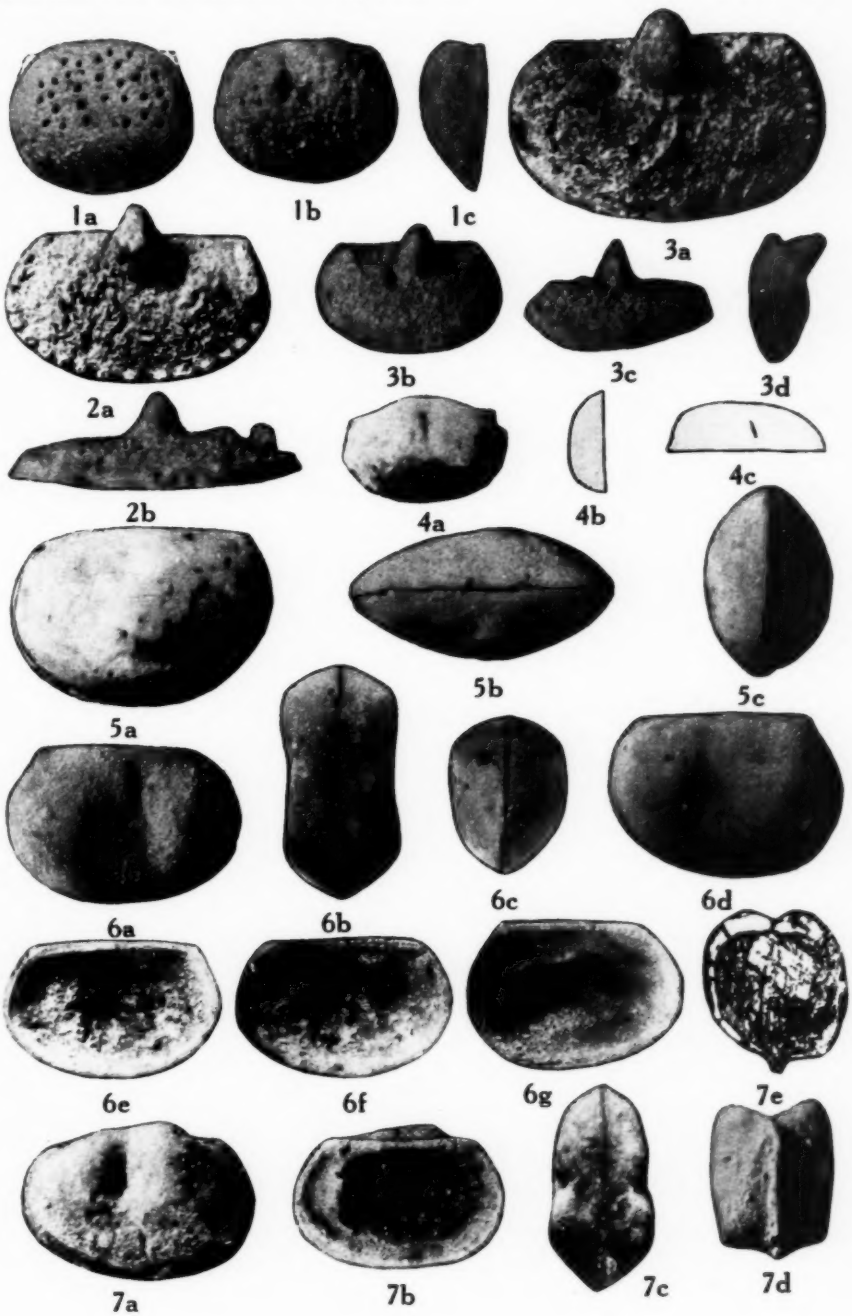
3a–d—Aechmina spinoterminata Swartz, n. sp. *3a*, Side view of squeeze of holotype, an external mold of a right valve, showing small spines along anterior margin, ×30. The impressions of the spines of the posterior margin can be seen in the mold, but are filled in, so that these spines are not seen on the squeeze. *3b–d*, Side, tilted ventral, and posterior views of squeeze from an external mold of another right valve, ×15. The spines of the terminal margins are not seen on this squeeze, although the filled in impressions can be seen on the mold. From upper half of Shriver chert, east side of Pine Creek, between Avis and Jersey Shore, Pa. (p. 564)

4a–c—Primitia mundula Jones, side view, and sketches of posterior and dorsal outlines, of Jones' holotype, a left valve. British Museum No. I.6880. Photograph and sketches by T. H. Withers. Silurian; from Jones' "No. 1 limestone" or specimen No. 1, of the Scandinavian drift of Berlin, Germany. (p. 565)

5a–c—Leperditella sp., left (?), dorsal, and anterior views of a carapace from the Silurian drift of Germany, provisionally identified as *Primitia mundula* by Krause, and deposited in the U. S. National Museum as a topotype of that species, ×30. U. S. N. M. No. 82414. The carapace is strongly inequivalved, and there is a scarcely discernible dorso-median sulcus. (p. 567)

6a–g—Primitia bonnemai Swartz, n. sp. *6a–c*, Right, dorsal, and posterior views of the holotype, a well preserved carapace, ×30, showing the median depressed area, and vertical sulcus. *6d*, Left side of a carapace, with obsolete vertical sulcus, ×30. *6e–g*, Interiors of two right valves and one left valve, ×30, showing the cardinal grooves and ridges. *6e* has one groove, *6f* and *g* two grooves. Talus of Silurian marl, brick quarries, Mulde, Island of Gotland. These specimens are preserved with Bonnema's collections, in the Mineralogical, Geological Institute of the National University, Gronigen, Holland. (p. 566)

7a–e—Milleratia cincinnatiensis (Miller) Swartz, n. gen. *7a*, Side view of typical left valve, showing the asymmetrical dorsal umbo, large dorso-median sulcus, and expanded free edges, ×37. *7b*, Interior of right valve, ×37. *7c, d*, Dorsal and posterior views of carapaces, ×37. *7e*, Anterior view of vertical transverse section of a carapace, taken just behind median sulcus, ×37; showing the dorsal umbos, expanded margins, and radial canals (?). Upper Ordovician, Richmond group, top of Lorraine beds, Clarksville, Ohio. Specimens loaned by U. S. National Museum, presumably identified by Dr. Ulrich. (p. 568)



Swartz, Paleozoic Ostracodes

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margin is narrowly rounded, and the greatest height is behind the middle. Ventral margin gently convex.

As seen in dorsal and edge views, the hingement appears simple, and there is no appreciable overlap. In separated valves, however, the cardinal surfaces are flattened and marked by one or two very shallow grooves, separating two or three faint longitudinal ridges. From the specimens seen, the interlocking of these faint cardinal grooves and ridges is not clear. They are not always odd in number in the one valve, even in the other. Some of the right valves, as here described and illustrated, have one, some two grooves. The free edges, as seen in interior views, are generally sharp; but in some of the larger specimens there is a faint groove along the ventral margin. This groove has been found in specimens of both valves. Sectioning of entire carapaces might clarify the relations of both the cardinal and ventral structures. The valves are somewhat thickened near their free margins, suggesting an inner lamella such as that described by Alexander (20*b*).

Each valve is strongly convex, with a broad, undefined, median to anteromedian depressed area; the regions in front of and behind this depression are more elevated than the area below it. A narrow vertical crease generally extends dorsally from the anterior part of the depressed area, but in a few specimens is very weak. Surface smooth. Sexual dimorphism is not shown by the specimens examined by the writer.

Measurements of a typical carapace are: length 1.02 mm., height 0.67 mm., thickness 0.51 mm.

Relationships.—As can be seen from the accompanying illustrations, *P. bonnemai* is very closely related to *P. mundula*. The chief distinguishing feature is the broad median sunken area of the former species. Also, the sulcus is not so nearly median in position. It is unfortunate that the dorsal angles of the holotype of *P. mundula* are not better preserved, and that the holotype was obtained from a piece of drift, so that there is no real type locality and horizon where search can be made for additional material.

Using *P. bonnemai* for information about the features not shown by the holotype of *P. mundula*, the genus *Primitia* can be described as follows:

Small, straight-backed Ostracoda, the carapace subovoid to lenticular in end view. Hingeline less than greatest length, the anterior cardinal angle more recessive than the other. Hinge simple, or bearing faint longitudinal grooves and ridges; free edges without distinct overlap. Surface of valve convex, with small, vertical, dorso-median sulcus; without ridges, knobs or marginal rim. Presumably without distinct sexual dimorphism.

As above defined, *Primitia* does not include the species from the Silurian drift of Germany, provisionally identified as *P. mundula* by Krause; or at least not the carapace sent by Krause to the U. S. National Museum under that name, and here illustrated as *Leperditella* sp. (Pl. 86, figs. 5*a–c*).

The Upper Ordovician species *Beyrichia cincinnatiensis* Miller, which has been cited as a typical American example of *Primitia*, must also be placed elsewhere. On the basis of specimens loaned to the writer by Dr. Bassler and presumably identified by Dr. Ulrich, it is here figured and described as the type of a new genus, *Milleratia*.

Occurrence.—Talus of Silurian marl, brick quarries, Mulde, Island of Gotland (11).

Genus MILLERATIA Swartz, n. gen.

Genotype: *Beyrichia cincinnatiensis* Miller.

Small, strongly unisulcate Ostracoda, each valve with a strong asymmetrical dorsal hump or swelling, highest posteriorly; carapace consequently heart-shaped in end view. Hingement apparently simple; overlap lacking or inconspicuous. Surface without knobs, ridges, or marginal rim, although the free edges may be a little expanded. Anterior car-

dinal angle more recessive than the posterior. Sexual dimorphism unknown.

Relationships.—Milleratia cincinnatiensis is the only species now referable to *Milleratia*. It differs from *Primitia* chiefly in the development of strong asymmetrical dorsal umbos. The expansion of the free edges of the valves is probably less significant. The shape of the carapace, including the umbos, and the character of the median sulcus, are very suggestive of the Kloedenellidae. (Pl. 84, figs. 2*a–l*.) *Milleratia* is left in the Primitiidae because it apparently lacks the sexual dimorphism of the Kloedenellidae, and is essentially equivalved. It may well, however, represent the stock from which the Kloedenellidae were derived.

MILLERATIA CINCINNATIENSIS (Miller)

Plate 86, figures 7*a–e*

Beyrichia cincinnatiensis MILLER, *1875*, Cincinnati Quart. Jour. Sci., 2, p. 350, text fig. 25.

Primitia cincinnatiensis MILLER, *1889*, North American Geol. Pal., p. 561, text fig. 1045. —ULRICH, *1890*, Cincinnati Soc. Nat. Hist., Jour., 13, p. 132, pl. 10, figs. 5, 6.—CUMMINGS, *1908*, Geol. Nat. Hist. Res. Ind., 32d Ann. Rept., p. 345, pl. 53, figs. 11–11d. —ULRICH and BASSLER, *1923*, Md. Geol. Surv., Silurian, p. 299, text fig. 15 (fig. 3.)—BASSLER and KELLETT, *1934*, Geol. Soc. Amer., Special Papers, 1, p. 440.

Carapace small; more or less subovoid in dorsal view, the greatest thickness behind the middle; subquadrate to heart-shaped in end view, the dorsal margin concave because of the dorsal humps of the valves; subovoid in side view, the dorsal margin modified by the strong asymmetrical dorsal humps; posterior cardinal angle obtuse, but more prominent than the anterior; greatest height behind middle. Hingement simple; overlap inconspicuous or wanting. Sexual dimorphism not apparent in specimens studied by the writer.

Valves strongly convex with broad, asymmetrical, dorsal umbos; dorso-median sulcus strong, deepest in its ventral part, lying a little in front of the middle; surface without knobs or ridges, although the free edges are somewhat expanded. No fine ornamentation.

Measurements of a representative carapace are: length 0.86 mm., height 0.58 mm., thickness 0.53 mm.

Occurrence.—Upper Ordovician, Richmond group, top of Lorraine beds, Clarksville, Ohio; Arnheim, Waynesville, of Ohio, Indiana, Michigan.

Hypotypes.—U. S. Nat. Mus. 41346.

Genus PRIMITIELLA Ulrich

PRIMITIELLA (?) VENTRICOSA Swartz, n. sp.

Plate 87, figures 1*a–d*

Carapace small, sublenticular to subovoid in dorsal view; elongate subquadrate in side view; dorsal margin straight, a little less than the greatest length; anterior margin rounded, somewhat extended. Hingement and overlap unknown.

Surface of valve moderately convex above, with a moderately impressed, very broad, poorly defined subvertical depression, deepest in its ventral part, a little in front of the middle. There is a high, longitudinal swelling in the ventral part of the valve, which merges with the general surface anteriorly but is abruptly terminated posteriorly. The surface is deflected, and forms a more or less distinct angulation between the ventral margin of the swelling, and the ventral edge of the valve. In some specimens the surface appears to be indistinctly granulose.

In internal molds, the impression of the median-sulcus is well defined, and there is a low node just in front of the sulcus, which represents a thinned area of the carapace and corresponds to the supposed eye-spot observed by Bonnema in *Primitia tolli* (Pl. 79, figs. 5*a*, *i*). There is also a series of spine-like projections near the ventral margin, evidently representing coarse internal openings at the ventral angulation.

The dimensions of a large valve are: length 0.78 mm., height 0.41 mm., greatest convexity in dorsal half 0.12 mm.,

greatest convexity of ventral swelling 0.19 mm.

Relationships.—The ventral swelling is suggestive of a brood pouch, but is present in all of the specimens so far observed, and apparently is not a dimorphic structure. Similar ventral swellings occur in species of *Kirkbyella* Coryell and Booth (24) (25), and it may prove desirable to place the present species in that genus. The described species of *Kirkbyella* are, however, coarsely reticulate, and the sulcus is better defined.

Occurrence.—Fairly common in *Metaplasia plicata* zone, middle part of Shriver chert, Curtin, Pa.; rare 70 feet above base of Shriver, Mount Rock, Lewistown, Pa.

Genus PYXIPRIMITIA Swartz, n. gen.

Genotype: *P. ventriclefta* Swartz, n. sp.

Carapace small, generally less than 1 mm., in length; oblong in dorsal view, the sides flattened, about parallel, the ends more or less truncated; subquadrate to subtrapezial in side view; dorsal margin straight, hinge a little less than the greatest length; ventral margin gently convex, ends more or less rounded. Overlap and hingement not observed, but valves probably equal or very nearly so.

Surface of valve fairly convex, flattened on top, rather sharply deflected along all the margins, including the dorsal margin. Marked at about the middle of the dorsal half by a well defined rather deep vertical sulcus, that typically is closed dorsally, and does not extend to the dorsal margin. Surface of flattened area marked by rather coarse, more or less rounded, relatively distant pits, of moderate depth.

Relationships.—*Pyxiprimitia* is closely allied to *Halliella* Ulrich, but lacks the more or less well defined border paralleling the free margins, commonly seen in members of that genus. The name refers to the box-like form of the carapace, resulting from the flattening of the surface, and deflection of the margins of the valves.

In addition to *Pyxiprimitia ventriclefta* and *P. ventripunctata*, the two new species here described, it seem probable that this genus should include *Primitia variolata* Jones and Holl (26), and *P. variolata* var. *paucipunctata* Jones and Holl (26), both of the Woolhope limestone of the Silurian of England. These species have the oblong dorsal aspect and distantly spaced coarse pits characteristic of the genus, although as figured the dorsomedian sulcus appears to be open dorsally. *Beyrichia sigillata* Jones, of the "Wenlock"?, Beechey Island, N.A., is said by Jones and Holl to be a close relative of *Primitia variolata*, but neither the figure nor the description gives the convexity of the valve.

PYXIPRIMITIA VENTRICLEFTA Swartz, n. sp.

Plate 87, figures 2*a–d*

Carapace suboblong in dorsal view, sides about parallel, ends truncated; more or less subrectangular in side view; dorsal margin straight, hinge about six-sevenths the greatest length; ventral margin gently convex; anterior and posterior margins moderately convex, projecting about equally beyond the hinge extremities; cardinal angles obtuse. Hingement apparently simple, judging from internal molds of separate valves; overlap not observed.

Surface of valve strongly elevated; flattened on top, sharply deflected along all the margins, although the summits of the deflected slopes are rounded and not angular. Dorso-median sulcus well defined, deeply impressed, about vertical, not reaching the dorsal margin; extending to about two-thirds the distance from the dorsal to the ventral margin; lying about on or a little in front of the middle of the valve. Areas to either side of the median sulcus marked by a number of moderately deep, fairly well defined, rather widely spaced pits, placed so that the marginal parts of the elevated

flattened area and the surfaces bordering the median sulcus are left smooth and unmarked. There are about seven or eight pits in front of the sulcus, ten or eleven in back of it. In one specimen the pits posterior to the sulcus are arranged in two vertical rows, but usually the arrangement is irregular. The smooth areas bordering the median sulcus tend to be elevated a little above the pitted areas. The ventral slope is also marked by a deep, relatively narrow longitudinal cleft, extending somewhat farther to the rear than to the front. The posterior end of the cleft lies about halfway up the steep ventral slope, the cleft rising somewhat anteriorly so that its anterior end is near the summit of the slope. There is usually a single strong pit just off the anterior end of the cleft, but in one specimen the anterior part of the cleft is broken into three pits.

Length 0.70 mm., height 0.46 mm., convexity of single valve 0.20 mm.

Relationships.—The most closely related known species is *Pyxiprimitia ventripunctata*, hereinafter described.

Occurrence.—Fairly common about 95 to 100 feet above the base of the Shriver chert, Hollidaysburg, Pa.

PYXIPRIMITIA VENTRIPUNCTATA Swartz, n. sp.

Plate 87, figures 3*a–h*

Carapace suboblong in dorsal view, the sides nearly parallel; subtrapezial to subsemielliptical in side view; dorsal margin straight, the hingeline slightly less than the greatest length; ventral margin gently convex; anterior margin moderately convex, somewhat extended; posterior margin truncated. Anterior angle rounded, recessive, posterior angle fairly sharp, protuberant. Hingement simple, judging from internal molds of separate valves; overlap not observed.

Surface of valve strongly elevated, flattened on top, sharply deflected along all the margins. Dorso-median sulcus well defined but narrow, rather deeply impressed, vertical; closed dorsally so that it does not reach the dorsal margin; extending to about halfway from the dorsal to the ventral margin; lying a little in front of the middle of the valve. Areas to either side of the median sulcus marked by seven to ten moderately deep, widely spaced, irregularly arranged pits, placed so that the marginal parts of the elevated flattened area, and the surfaces bordering the median sulcus, are smooth In addition, there is a longitudinal row of about five pits near the summit of the steep ventral slope.

In internal molds, the surface pits are weakly reflected, showing that the carapace is very thin at the floors of the pits. The impression of the median sulcus is enlarged. There is a low node in front of the sulcus, which represents a local thinning of the carapace, as in *Primitiella* (?) *ventricosa* and *Primitia tolli*.

Length of the largest valve observed 0.76 mm., height 0.52 mm., convexity 0.15 mm. Length of a valve of average size 0.64 mm., height 0.42 mm., convexity 0.15 mm.

Relationships.—This species is very similar to *Pyxiprimitia ventriclefta*, previously described in this paper; but the strong ventral longitudinal cleft of that species is represented here by a longitudinal row of pits, the dorso-median cleft is distinctly narrower, and the posterodorsal angle more extended.

Occurrence.—Common in the *Metaplasia plicata* zone of the middle part of the Shriver chert, Curtin, Pa.

Family HOLLINIDAE Swartz

Genus PARABOLBINA Swartz, n. gen.

Genotype: *Ctenobolbina granosa* Ulrich.

Carapace small, sublenticular in dorsal view; more or less subsemielliptical to subtrapezial in side view; hingeline straight, a little less than the greatest length, other margins more or less rounded. Hingement apparently simple; overlap unknown. Surface of valve moderately, more or less evenly convex,

marked at or a little in front of the middle of the dorsal half by a short, fairly deep, generally not well defined subvertical sulcus. Surface more or less swollen below the end of the sulcus, forming an indistinct longitudinal hump that merges with the general surface of the valve at the front and back. Surface without a true border, but provided with a frill or spines near the ventral edge; strongly granulose, at least in the typical species.

Relationships.—This genus is proposed for two new ostracodes described in this paper, and one previously described species, *Ctenobolbina granosa* Ulrich (27), of the Lower Devonian New Scotland limestone of New York (Pl. 80, fig. 2). This Lower Devonian assemblage differs from *Primitia* and its close allies in the development of spines or frills near the ventral margin, in the tendency to develop a longitudinal hump below the dorso-median sulcus, and in the strongly granulose rather than smooth or pitted surface. It is quite different from the typical Ordovician members of the genus *Ctenobolbina*. These have, it is true, a sulcate, granulose surface, and tend to develop submarginal frills or spines; but they generally have two well marked sulci that extend well across the valve, nearly to the ventral edge. Even the unisulcate species which seem to belong with *Ctenobolbina*—including *Ctenobolbina bispinosa* Ulrich (28), the species to which Ulrich considered *P. granosa* most closely related—have the sulcus extended nearly to the ventral margin, and lack the ventral swollen region. The comparatively short sulcus and more or less swollen ventral region are somewhat suggestive of the Carboniferous genus *Beyrichiella;* but, as typified by *Beyrichiella cristata*, that genus tends to develop a narrow marginal border, lacks the spines and frills, and the median sulcus tends to have strong lateral extensions at its lower end. *Beyrichiella bifurcata* Kummerow (29) of the Upper Silurian Beyrichienkalk of Europe is very suggestive of *Parabolbina*, and may belong here, although the two lateral extensions from the ventral end of the median sulcus are so strong that they give the valve a different aspect.

The frill and spines and strongly granulose surface of the members of this genus suggest derivation from *Ctenobolbina* rather than directly from *Primitia* or other Primitiidae.

PARABOLBINA LIMBATA
Swartz, n. sp.

Plate 87, figure 4

Carapace sublenticular in dorsal view; subsemielliptical to subtrapezial in side view; hingeline straight, about five-sixths the greatest length; anterior and posterior margins about equally protuberant, but the anterior end is more regularly rounded and somewhat higher than the posterior. Dorsal angles obtuse, about equal. Greatest height in front of middle. Hingement and overlap not observed.

Surface of valve rather strongly convex, sloping more or less regularly to all the margins, without a marginal border; marked about on or just in front of the middle of the dorsal half by a moderately deep but not well defined subvertical sulcus, which is open dorsally, but does not continue down the dorsal slope to the hinge margin; just behind the upper end of the sulcus the surface is raised into a scarcely discernible low undefined swelling, and the sulcus is a trifle constricted by another very low indistinct undefined swelling on its anterior side at about its middle. The sulcus extends a trifle below the middle of the valve, where scarcely perceptible extensions fork forward and backward from its shallow ventral end. Below the sulcus the surface of the valve is swollen into a low broad undefined longitudinal bulge. A stout spine projects from the ventral slope a little behind the middle of the ventral edge, and from this spine a wide thin frill extends forward nearly to the antero-dorsal angle, paralleling the free edge. The frill is marked by five or six broad radial undulations. The sur-

face of the valve, excluding the frill and spine, is marked by rather coarse granules.

Length and height of valve minus spine and frill 0.82 mm., and 0.57 mm., respectively; convexity 0.25 mm.

Relationships.—*Parabolbina* (*Ctenobolbina*) *granosa* (Ulrich) (27), of the New Scotland of New York, is very close to this species, having the same kind of sulcus and frill, the same longitudinal swelling below the sulcus, and a similar granulose surface; but it apparently lacks the stout spine, and is more elongate. *P. ventrispinosa* is the only other known closely related species.

Occurrence.—Rare 90 to 100 feet above the base of the Shriver chert, Hollidaysburg, Pa.; very rare, 70 feet above base of Shriver, Mount Rock, Lewistown, Pa.; very rare, *Metaplasia plicata* zone of the middle part of the Shriver, Curtin, Pa.

EXPLANATION OF PLATE 87

FIGS. *1a–d*—*Primitiella* (?) *ventricosa* Swartz, n. sp. *1a*, Side view of squeeze from holotype, a natural external mold of a left valve, ×30. *1b*, Internal mold of a left valve, ×30; showing impression of the internal hollow in front of sulcus, and spines representing the internal pores at the ventral angulation. *1c, d*, Side and dorsal views of squeeze of smaller left valve, ×30. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. (p. 568)

2a–d—*Pyxiprimitia ventriclefta* Swartz, n. gen. and n. sp., views of syntypes, ×30. *2a, b*, Side and ventral views of squeeze from external mold of a left valve. *2c, d*, Side views of squeezes from external molds of two right valves, the second with the posterior pits arranged in two parallel rows. 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa. (p. 569)

3a–h—*Pyxiprimitia ventripunctata* Swartz, n. sp. *3a*, Side view of squeeze from holotype, an external mold of a right valve, ×30. *3b, c*, Side and dorsal views of a squeeze from external mold of a large left valve, ×30. *3d–f*, Side views, the second tilted, of squeezes from external molds of two right valves, ×30. *3g, h*, Side views of two internal molds, ×30; showing impression of internal hollow just in front of the sulcus. In *3g*, the impressions of the external pits are abnormally strong. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. (p. 570)

4—*Parabolbina limbata* Swartz, n. sp., side view of squeeze from holotype, an external mold of a right valve, ×30. 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa. (p. 571)

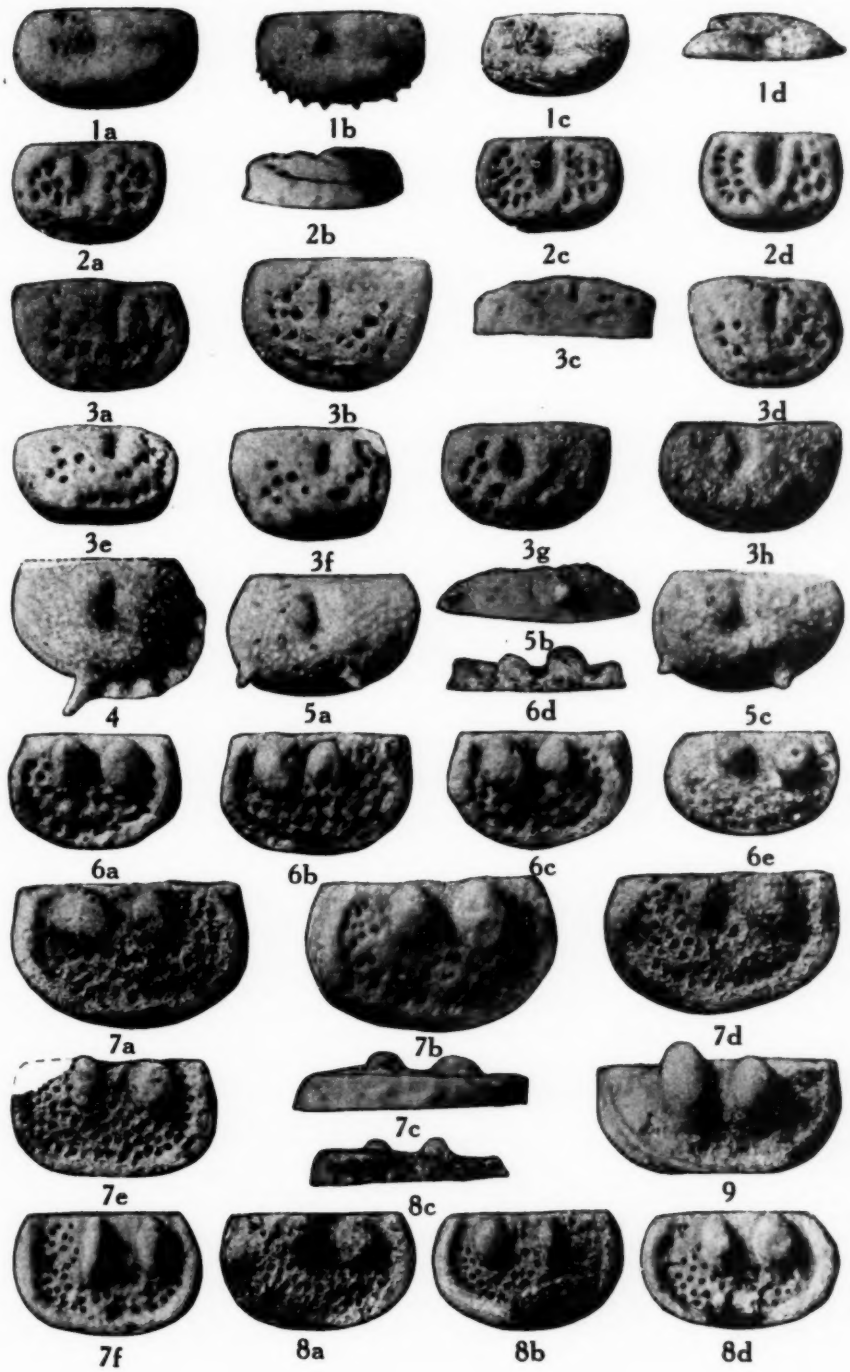
5a–c—*Parabolbina ventrispinosa* Swartz, n. sp. *5a, b*, Side and ventral views of squeeze from holotype, a natural external mold of a left valve, ×30. *5c*, Side view of squeeze from mold of another left valve, ×30. 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa. (p. 573)

6a–e—*Ulrichia affinis* Bassler and Kellett. *6a–d*, Side views of squeezes from external molds of a right, and two left valves, and a dorsal view of the third squeeze, ×30. *6e*, Side view of internal mold of a right valve, ×30; showing weak reflection of the external pits. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. (p. 578)

7a–f—*Ulrichia pluripuncta* Swartz, n. sp. *7a–d*, Side views of squeezes from syntype, external molds of a left, and two right valves, with a ventral view of the second squeeze, ×30. Trilobite beds of upper part of Shriver chert, Curtin, Pa. *7e, f*, Side views of squeezes from two external molds, ×30; showing variations in shape, number of puncta, and length of posterior knob. 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa. (p. 578)

8a–d—*Ulrichia terminata* Swartz, n. sp. *8a*, Side view of squeeze from holotype, an external mold of a right valve, ×30. Trilobite beds of upper part of Shriver chert, Curtin, Pa. This species may be dimorphic with the associated *U. pluripuncta*. *8b, c*, Side and ventral views of squeeze from external mold of a left valve, ×30. *8d*, Side view of squeeze from an external mold of a right valve with abnormal development of posterior part of marginal ridge, ×30. 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa. (p. 579)

9—*Kellettina robusta* (Kellett), Swartz n. gen. Left valve, ×25. Permian, Wreford formation, Kansas. (p. 585)



Swartz, Paleozoic Ostracodes

UNIV OF MICH.

PARABOLBINA VENTRISPINOSA
Swartz, n. sp.

Plate 87, figures 5*a–c*

Carapace sublenticular in dorsal view, sides a little flattened, greatest thickness behind the middle; subovate to subtrapezial in side view; hingeline straight, about four-fifths the greatest length; ventral margin gently convex; anterior margin regularly rounded; postero-dorsal region somewhat extended. Hingement apparently simple judging from internal molds of separate valves; overlap not observed.

Surface of valve rather strongly convex, sloping more or less regularly to all the margins, without a border; marked just behind the middle of the dorsal half by a moderately deep, but not well defined subvertical sulcus, that is open dorsally, but does not continue down the dorsal slope to the hinge margin; the sulcus is somewhat constricted by a very low scarcely discernible undefined round swelling on its anterior side, about one-third the distance below the dorsal margin; at its ventral end the sulcus flares open somewhat, but can not be said to bifurcate. Below the sulcus the surface is slightly elevated, forming an undefined longitudinal swelling, the summit of which is as highly elevated as the regions in front of and behind the median sulcus. On the ventral slope, some distance from the free edge, are two rather stout spines, the postero-ventral one about one-third the distance from the posterior margin, and somewhat larger than the antero-ventral spine, which lies below and just behind the anterior extremity. The spines if perfect would probably be a little longer than shown in the figures. The surface in addition is coarsely granulose, the flat interspaces between the granules being about as wide as or a little wider than the diameter of the granules. The granules are strongest on the more highly elevated parts of the surface, less conspicuous elsewhere, and become obsolete on the floor of the median sulcus.

Length of an average valve: 0.84 mm., height 0.52 mm., convexity 0.18 mm.; granules about 0.02 mm., in diameter.

Relationships.—This species is closely related to the associated *Parabolbina limbata* (30), but is somewhat more elongate, and has two ventral spines instead of the large ventral spine and broad undulated frill of that species. It is also somewhat suggestive of *Ctenobolbina bispinosa* Ulrich (28) of the Upper Odovician of Ohio, but in that species the two spines are placed respectively in the postero-ventral and postero-dorsal parts of the valve, the median sulcus is long, extending at least two-thirds the distance from the dorsal to the ventral margin, and the area below the sulcus is not swollen.

Occurrence.—Moderately common 90 to 100 feet above the base of the Shriver chert at Hollidaysburg, Pa.; rare in the *Metaplasia plicata* zone of the middle part of the Shriver at Curtin, Pa.

Family DREPANELLIDAE Swartz

Genus BOLLIA Jones and Holl

The species of *Bollia* described in this paper all possess an inner U-shaped ridge and a more or less well developed marginal ridge. They have no suggestion of the small third lobe commonly found in the Zygobolbinae, and lack the dimorphic pouches developed by the members of that subfamily. They fall into three rather distinct sections. In the first, including *B. sagittaformis* and *B. burgeneri*, the marginal ridge is strong and extends along the free margin from dorsal angle to dorsal angle; the inner ridge has at least one enlarged but flattened end; and the surface is apparently marked by minute, rather distant, elongate depressions. In the second, including *B. americana* var. *zygocornis*, the marginal ridge is moderately well developed, the ends of the inner ridge form highly elevated as well as thickened knobs, and the surface is crowded with minute papillae. In the third section, which includes *B. cristata* and *B. ungula*, the marginal ridge is low, the inner ridge does not have distinctly bulbous ends, and the surface appears to be smooth.

Among other described species, *B. irregularis* Ulrich and Bassler and *B. haraganensis* Roth are closely related to *B. sagittaformis;* while *B. bicollina* Jones and Holl, *B. hindei* Jones, *B. obesa* Ulrich, and *B. americana* Ulrich and Bassler are all very close to *B. americana* var. *zygocornis*. On the other hand, *B. nitida* Ulrich and Bassler and *B. immersa* Ulrich and Bassler of the Silurian of Maryland do not belong in any of the above groups. In these two species, the marginal ridge is weak, the inner ridge is low, regular, and encloses a relatively deep sulcus, and the area between the ridges is coarsely punctate. These species should probably be referred to *Jonesites* Coryell.

BOLLIA SAGITTAFORMIS
Swartz, n. sp.
Plate 88, figures 1*a–f*

Carapace moderately large, suboblong in dorsal view, the sides about parallel; subquadrate in side view; hingeline straight, a little less than the greatest length; ends more or less rounded, the posterior end somewhat higher than the anterior. Cardinal angles about equally obtuse. Hingement apparently simple. Judging from an impression of part of a carapace, the left valve slightly overlaps the right along the free margins; but this apparent overlap may be due to distortion of the specimen.

A rounded, well developed ridge, of moderate width, extends the entire length of the free margins; it rises almost vertically from the edges, except along the posterior margin where there is a distant flange; it is somewhat lower along the ventral margin than elsewhere, and is thickest in its anterior part. The inner ridge is elevated a little more than the marginal ridge; it declines dorsally, the ends reaching just about to the dorsal margin; it is U-shaped, but with the limbs converging a little above, the anterior limb more nearly vertical than the other; the posterior limb is narrow, rounded, bending sharply into the slightly lower ventral part; the anterior limb is expanded on its inner side, forming a triangular, harpoon-shaped knob, flattened on top. In the best preserved specimens the surface of the ridges appears to be marked by irregularly placed, comparatively distant, more or less rhomboidal, shallow depressions, their centers about 0.04 mm. apart, the interspaces relatively wide, flat. The rest of the surface appears to be smooth.

In internal molds, the ventral part of the marginal ridge is nearly obsolete, the outline of the subtriangular lobe of the inner ridge is subdued, and the ventral part of the inner ridge is low, with the adjacent area somewhat swollen.

The dimensions of an average valve are: length 1.72 mm., height 1.08 mm., maximum elevation of ridges about 0.45 mm., height of marginal ridge at middle of ventral sag 0.27 mm.

Associated with the material described above there are more elongate, much more unequal-ended specimens, with the space between the posterior limbs of the two ridges proportionately wider. These elongate specimens might well be separated as a distinct variety. At present however, they do not seem to have stratigraphic value, and a similar variation is observed in *B. burgeneri*. Length of a valve of this type: 2.26 mm., height 1.19 mm., maximum elevation of ridges 0.48 mm.

Orientation.—The orientation of *B. sagittaformis* and other species of *Bollia* and *Ulrichia* described in this paper, is very uncertain and unsatisfactory. There is little difference in recessiveness of the cardinal angles. The orientation used for description is consequently based on the supposition that the depression enclosed by the inner ridge represents the median sulcus of the Primitiidae and Kloedenellidae (Pl. 84 and 85), and that this sulcus is anterior in position. The more persistent knob of the inner ridge is placed in front of the sulcus, and this knob may correspond to the incipient knob in front of the sinus in *Primitia tolli* (P. 85, fig. 1*b*).

Relationships.—*B. sagittaformis* is very

close to the species, *B. burgeneri*. *B. haraganensis* Roth of the Lower Devonian Haragan beds of Oklahoma, and *B. irregularis* Ulrich and Bassler of the Lower Devonian New Scotland limestone of Maryland, are related species, but differ in the characters of the swellings of the inner ridge.

Occurrence.—Rare, 55 and 80 feet above base of Shriver chert, Hollidaysburg, Pa.; common in *Metaplasia plicata* zone of Shriver, Curtin Pa.; common in slab collected by J. B. Payne near Altoona, 1918.

BOLLIA BURGENERI
Swartz, n. sp.

Plate 88, figures 2*a–g*

Shape of carapace, extent, size, and elevation of ridges, and fine surface detail as in *B. sagittaformis*, except that the dorsal part of the posterior limb of the inner ridge is enlarged on its inner side to form a rounded, somewhat flattened knob.

The dimensions of a rather large valve are: length 1.90 mm., height 1.10 mm., maximum elevation of ridges 0.40 mm., elevation of marginal ridge at ventral sag 0.30 mm.

Part of the variation in shape of the figured specimens is probably due to distortion. However, there is the same variation from the more typical subquadrate specimens to more elongate individuals with strongly unequal ends, that is seen in *B. sagittaformis*. This parallelism in variation in outline is an interesting phenomenon, and raises problems as to the genetic relationships of the four groups of individuals.

There is considerable variation in the strength of the rounded swelling of the inner ridge in specimens of *B. burgeneri*. Because of the transitional specimens with weak swellings, *B. burgeneri* and *B. sagittaformis* might be considered varieties of one species. Furthermore, the two forms do not seem to have different stratigraphic ranges.

The enlargement of the posterior limb of the inner ridge was first recognized by Mr. Glen Burgener, who assisted the writer in collecting specimens at Hollidaysburg and Lewistown, and for whom this species is named.

Occurrence.—Common 55 feet above base of Shriver chert, Hollidaysburg, Pa.; common 67 and 70 to 75 feet above base of Shriver, Lewistown, Pa.; common *Metaplasia plicata* zone of middle part of Shriver, Curtin, Pa.

BOLLIA AMERICANA var. ZYGOCORNIS
Swartz, n. var.

Plate 88, figures 3*a–g*

Beyrichia sp. CLARKE, *1900*, N. Y. State Museum, Mem. 3, pl. 9, figs. 14, 15.

Carapace more or less subquadrate in side view, length to height about 3 to 2; hingeline straight, somewhat less than greatest length of carapace; ventral margin gently convex; ends rounded, about equal. Hinge apparently simple. On one impression of part of a carapace, the right valve overlaps a little on the left along the ventral margin, but this may be due to squeezing of the specimen.

Surface of valve marked by a rather narrow marginal ridge, and by a stronger inner, bulbous, U-shaped ridge. The marginal ridge extends from near the anterodorsal angle to about half way up the posterior margin, where it is generally somewhat thickened. This ridge is close to the edge along the ventral margin, but is set some distance from the edge at the anterior and posterior ends of the valve. The inner ridge is separated from the outer one by a comparatively narrow, flat-bottomed to rounded furrow, widest posteriorly. The ventral part of the inner ridge is rather low, but each end is swollen into a high, thickened knob. The anterior knob is long, extending more than half way from the dorsal to the ventral edge of the valve; it is slightly constricted a little above its middle by a shallow transverse furrow, the part below the furrow being longer and more elevated than the part above it. The posterior knob is nearly as high, but is short and rounded. The yoke connecting the two terminal knobs is raised into a

third smaller node at its postero-ventral bend. The sulcus enclosed by the inner ridge tends to be a trifle deeper than the furrow between the outer and inner ridges, and is deepest near the margin of the anterior knob. It flares anteriorly at its ventral end, below the anterior knob, where the yoke is constricted. Entire surface covered by small, rounded crowded papillae.

Length of the largest observed specimen: 2.26 mm., height about 1.30 mm. In most of the specimens the length is about 2 mm.

Orientation.—The orientation here used for description agrees with that used by Ulrich and Bassler for *B. americana* (1*a*) and corresponds to that used here for *B. sagittaformis* and *B. burgeneri*, as is shown by the position of the larger knob of the inner ridge. This orientation places the greatest thickness in the anterior part of the carapace. The comparative orientation of the various species of *Bollia* described here seems well assured, even though the orientation in terms of the formerly enclosed animals is not clear.

Relationships.—An internal cast of *B. americana* var. *zygocornis* from the Oriskany beds of Becraft Mountain, New York, was figured by Clarke as *Beyrichia* sp., without description. This variety is very close to *B. americana* Ulrich and Bassler of the Shriver of Maryland and Pennsylvania, but the latter lacks the small third knob of the yoke of the inner ridge. However, the inner ridge is thickened at this place, and there seem to be all variations between individuals without, and individuals with a well developed third knob.

The Middle Devonian *B. hindei* Jones (31), *B. bilobata* Jones (31*a*) and *B. obesa* Ulrich (28*a*), are all closely related to *B. americana* and *B. americana* var. *zygocornis*, but differ in shape and development of the knobs of the inner ridge. Also, the marginal ridge extends from dorsal angle to dorsal angle in all three of those species.

Occurrence.—Common 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa.; common 105 to 110 feet above base of Shriver, Lewistown, Pa.; rare in material from upper half of Shriver near Jersey Shore, Pa.; common in middle and upper parts of Shriver, Curtin, Pa.

BOLLIA CRISTATA Swartz, n. sp.

Plate 88, figures 4*a–e*

Bollia ungula ULRICH AND BASSLER, *1913*, (not *B. ungula* Jones) Md. Geol. Survey, Lower Devonian, p. 528, pl. 96, figs. 20–22.

Carapace small, subquadrate to subelliptical in side view; hinge line straight; ventral margin gently convex; ends rounded, about equal in convexity and height; cardinal angles obtuse, about equal. Hingement and overlap not observed.

Marginal ridge nearly obsolete, although the surface rises sharply from the free edges, and then flattens out to form a platform around the inner ridge. Inner ridge thick, strongly elevated, its summit almost uniform in height throughout; thickness nearly constant, but little less at the ventral bend than elsewhere; anterior limb with rounded summit; posterior limb rising gradually on its inner side, somewhat flattened on top, the outer slope abrupt, producing a well marked crest. Sulcus enclosed by inner ridge not very well defined, deepest in its anterior part. Fine surface ornamentation not observed.

Length of average valve 1.1 mm., height 0.7 mm.

Relationships.—This species is close to the Middle Devonian *B. ungula* Jones, hereinafter described on the basis of material from the type locality near New Bloomfield, Pennsylvania; but is distinguished by its smaller size, the obsolescence of the furrow separating the inner and marginal ridges, the greater thickness of the inner ridge at its ventral bend and the correspondingly lesser length of the enclosed sulcus, and especially by the continuous crest on the outer side of the posterior limb of the inner ridge. The material from the Shriver of Maryland described as *B. ungula* by Ulrich and

Bassler, presumably is identical with *B. cristata* of the Shriver of Pennsylvania.

Occurrence.—Common 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa.; common 105 to 110 feet above base of Shriver, Lewistown, Pa.; common in middle and upper parts of Shriver, Curtin, Pa.; fairly common in material from upper half of Shriver, near Jersey Shore, Pa.; common in slab collected near Altoona, Pa., by J. B. Payne in 1918.

BOLLIA UNGULA Jones

Plate 88, figures 5*a–c*

Bollia ungula (Claypole Ms.) JONES, *1889*, Am. Geol., vol. 4, p. 338, fig. 10, not figs. 11–13.—ULRICH, 1891, Jour. Cincinnati Soc. Nat. Hist., vol. 13, p. 188, pl. 14, figs. 6a, b.—ULRICH and BASSLER, *1908*, Proc. U. S. Nat. Museum, vol. 35, p. 288.—KINDLE, *1912*, U. S. Geol. Survey, Bull. 508, p. 113, pl. 9, fig. 9, not fig. 10.—ULRICH and BASSLER, *1913*, Md. Geol. Survey, Middle and Upper Devonian, p. 336, pl. 44, fig. 7, not fig. 8.—Not *Bollia ungula* ULRICH and BASSLER, *1913*, Md. Geol. Survey, Lower Devonian, p. 528, pl. 96, figs. 20–22.

On the basis of material collected from Claypole's locality by Dr. Bradford Willard, the writer is here illustrating and briefly describing specimens believed to be typical *B. ungula*. The specimens vary considerably in length, presumably due to distortion. The apparently more normal specimens are fairly elongate, with long straight hinge, subequal cardinal angles, the anterior end more regularly rounded and more extended than the posterior. There is a low rounded marginal ridge paralleling the free edges from angle to angle, and separated from the inner ridge by a narrow, moderately deep groove. The inner ridge is strongly elevated, with thick, nearly parallel vertical limbs, and narrow ventral bend. The summits of the ventral limbs are rounded, except for a small narrow flattened area near the base of the posterior limb. This small flattened area is bordered on its outer side by a well defined, curving crest.

The dimensions of an elongate valve are length 1.80 mm., height 0.90 mm.

Relationships.—Among the specimens illustrated by Jones in 1889, the specimen shown in his figure 10 corresponds with the material here illustrated, although it is relatively short. A species with a somewhat bulbous inner ridge is illustrated by Jones' figure 12a, b. A third probably distinct species, in which the ventral part of the inner ridge is considerably thickened, is illustrated by his figure 13. Kindle's pl. 9, figure 9, republished by Ulrich and Bassler in 1913 as their pl. 44, figure 7, represents a typical specimen of *B. ungula*, whereas Kindle's pl. 9, fig. 10, republished by Ulrich and Bassler as pl. 44, fig. 8, shows a specimen in which one end of the inner ridge is distinctly bulbous.

Occurrence.—Buff Onondaga (?) shale, along Susquehanna River and Western R.R., eastern outskirts of New Bloomfield, Perry Co., Pa.

Genus ULRICHIA Jones

Small, straight-backed Ostracoda, subquadrate to subelliptical in side view; surface of valve more or less flattened, with a well developed ridge along the free margins; typically with two rather large knobs near the dorsal margin, although one of the knobs may be obsolete. Surface, other than the knobs and rim, coarsely punctate. The hinge is probably simple, and the valves essentially equal, although fully satisfactory data on these features are lacking.

Genotype: *Ulrichia conradi* Jones.

Relationships.—The dorsal knobs and strong marginal ridge of the members of this genus are very suggestive of *Bollia*, although it is possible that *Ulrichia* was separately evolved from such primitiid genera as *Halliella* or *Jonesites*.

In the writer's opinion, the Carboniferous *Ulrichia robusta* Kellett (Pl. 87, fig. 9) must be removed from *Ulrichia*, along with related Late Paleozoic species. They are here referred to the new genus *Kellettina*, described in the accompanying footnote (32), and are referred to the *Kirkbyidae*. Some other species placed in *Ulrichia* need study, and evidently

will have to be removed from *Ulrichia* as here revised.

ULRICHIA AFFINIS Bassler and Kellett

Plate 87, figures 6*a–e*

Ulrichia aequalis ULRICH AND BASSLER, *1913*, [not *U. aequalis* (Jones and Holl)] Md. Geol. Survey, Lower Devonian, p. 518, pl. 95, fig. 11.

Ulrichia affinis BASSLER AND KELLETT, *1934*, Geol. Soc. Am., Special Papers, No. 1, p. 488.

Carapace truncated elliptical in side view; hingeline straight, about five-sixths the greatest length; ventral margin gently convex; ends more or less regularly rounded, about equal in height. Cardinal angles slightly obtuse, about equal. Hingement apparently simple, judging from molds of separate valves; overlap not observed.

Surface of valve flattened, bordered along the free margins by a moderately strong, rounded ridge, which is generally strongest anteriorly, and rises a little less abruptly from the posterior than from the ventral and anterior edges. There are two prominent knobs in the dorsal part of the valve; the anterior knob is slightly elongated dorso-ventrally, nearly twice as large as the other, and lies well in front of the middle of the valve. The posterior knob is also rounded, and is slightly post-median in position. The knobs are about equally elevated, with their summits considerably above the level of the marginal ridge, and are separated by about half the diameter of the posterior knob. Between the knobs there is a narrow, moderately deep, vertical sulcus, corresponding to the median sulcus of the Primitiidae. The surface enclosed by the marginal ridge is gently convex, highest just below the posterior knob, so that, if the knobs and marginal ridge are excepted, the carapace is thickest at this place. Except for the sulcus, and the knobs and ridge, the surface is marked by about 35 to 45, coarse, rather deep, more or less rounded puncta. On internal casts, the impressions representing the puncta are very weak, showing that the floors are thin.

Length of an average valve: 0.78 mm., height 0.48 mm., elevation of marginal rim 0.13 mm., total elevation of summit of anterior knob 0.20 mm., diameter of pits about 0.03 mm.

Relationships.—The material here described is apparently conspecific with *Ulrichia affinis* Bassler and Kellett of the Shriver chert of western Maryland, although that species was described and figured by Ulrich and Bassler as having essentially equal knobs and a very faintly reticulate surface. The holotype is unfortunately a weathered valve, and the apparent faintness of the puncta is evidently due to the condition of preservation. It is closely similar in appearance to the internal mold shown on Pl. 87, fig. 6*e*.

Occurrence.—Common in *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa.

ULRICHIA PLURIPUNCTA Swartz, n. sp.

Plate 87, figures 7*a–f*

Carapace truncated elliptical in side view; the hingeline straight, a little less than greatest length, the posterior angle slightly produced; ventral and terminal margins moderately convex. Hingement apparently simple, judging from molds of separate valves; overlap not observed.

Surface of valve flattened, bordered along free margins by a rounded ridge, best developed anteriorly, and rising less abruptly from the posterior than from the anterior and ventral edges. There are two prominent rounded knobs in the dorsal half of the valve; the anterior knob is much larger than the posterior one, is somewhat elongated dorso-ventrally, is situated well in front of the middle, and is separated from the posterior knob by about the diameter of the latter. Just posterior to the anterior knob is a shallow undefined sulcus, widening dorsally. Surface enclosed by marginal ridge gently convex, highest just below the posterior knob, so that this is point of greatest thickness of carapace, except for the knobs. Surface, not including the sulcus, knobs, and ridge, marked by

about 55 to 65, more or less rounded, fairly coarse, rather deep puncta. In internal molds, the impressions of the puncta are very weak. Length of a large valve: 1.00 mm., height 0.60., maximum height of marginal ridge 0.20 mm., total elevation of anterior knob 0.24 mm., diameter of pits 0.02 to 0.03 mm.

In addition to the above described typical material from the upper Shriver at Curtin, Pa., the writer is also including in this species slightly smaller specimens from the upper Shriver at Hollidaysburg, Pa. The latter tend to be more subquadrate, the sulcus adjacent to the anterior lobe is frequently very obscure, and the number of puncta ranges upward to about 80. In one of the Hollidaysburg specimens the anterior knob is exceptionally elongate, but this seems to be a mutational and not really a specific character.

Relationships.—*Ulrichia pluripuncta* is very close to *U. affinis*, but is larger, the dorsal knobs are relatively farther apart, the sulcus is weaker, and occupies a smaller proportion of the space between the knobs, and the puncta are distinctly more numerous and not quite so coarse. As has been pointed out, these changes, except as to size, have been carried a little farther in the Hollidaysburg than in the Curtin material, so that the Hollidaysburg specimens might be considered a distinct variety or species.

Ulrichia terminata, may prove to be dimorphic with *U. pluripuncta*.

Occurrence.—Common, upper part of Shriver chert, Curtin, Pa.; common, 90 to 110 feet above base of Shriver, Hollidaysburg, Pa.; rare in some material from upper half of the Shriver, east side of Pine Creek, between Avis and Jersey Shore, Pa.

ULRICHIA TERMINATA Swartz, n. sp.

Plate 87, figures 8*a–d*

Outline of carapace, and surface of valves as in *Ulrichia pluripuncta*, except that the marginal rim is well developed along the anterior and antero-ventral margins, becomes obsolete along the ventral margin, and is generally lacking or only weakly developed along the posterior margin.

Length of the holotype: 0.84 mm., height 0.53 mm., diameter of pits 0.02 mm.

Relationships.—The marked similarity between *Ulrichia terminata* and the associated *U. pluripuncta*, except for the changes in the marginal ridge, suggests that the two forms are really dimorphic. If this is correct, then the "anterior" sausage-shaped swelling of *U. terminata* would presumably be some sort of brood pouch. This would be a grave objection to the orientation here used for *Ulrichia*. The only reason for doubting that *U. terminata* is a dimorph of *U. pluripuncta* is the fact that no such dimorph could be found for *U. affinis*, although many specimens were obtained and examined. No similar associated form has been reported with the closely related *Ulrichia conradi*, but this species has never been carefully studied.

Occurrence.—Rare, upper part of Shriver chert, Curtin, Pa.; rare 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa.

Family BEECHERELLIDAE Ulrich

Genus ACANTHOSCAPHA Ulrich and Bassler

ACANTHOSCAPHA PENTAGONALIS Swartz, n. sp.

Plate 89, figures 1*a–g*

Carapace fairly large, subpentagonal in dorsal view, the anterior end truncated, the sides flattened, diverging to position of greatest thickness about three-fourths the distance to the posterior end, then converging rapidly to the pointed posterior terminus. Carapace elongate subreniform in side view; dorsal margin strongly convex, rounding into the ends; ventral margin straight or slightly concave, the post-ventral bend extended and bluntly angulated, the anterior end more rounded. In end or cross-section view the carapace is thick, semielliptical in outline, broadly rounded

above, the sides flattened and nearly parallel, bending very abruptly into the wide flat ventrum. On the ventrum, there are low rounded ridge-like swellings at the margins of the posterior flanks. Hinge apparently simple, seemingly without overlap, about two-thirds the length of the carapace. Free edges expanded to form strong contact flanges along the ventral and part of the anterior margins; these flanges are strongest in the posterior half of the ventral margin. Several external molds of carapaces show some overlap of the left upon the right valve; but this may be due to squeezing, as one such mold shows no overlap, and in another the right valve appears to overlap the left. Surface smooth.

In internal molds there is a small round flattened elevation, a little below and in front of the middle of the valve, evidently representing an impressed muscle scar on the interior of the valve.

Length of a large left valve 1.95 mm., height 0.91 mm., convexity 0.45 mm.

Relationships.—Acanthoscapha pentagonalis lacks the strong posterior spine of the typical members of the genus, but the reniform outline, simple hinge, peculiar flat ventrum, and angulated post-ventral bend show that it is a close ally of the described species of *Acanthoscapha* and *Beecherella*. Several specimens from the *Metaplasia plicata* zone of the middle part of the Shriver at Curtin, Pa., appear to have a small node on the outer rounded antero-ventral part of the valve, a fea-

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EXPLANATION OF PLATE 88

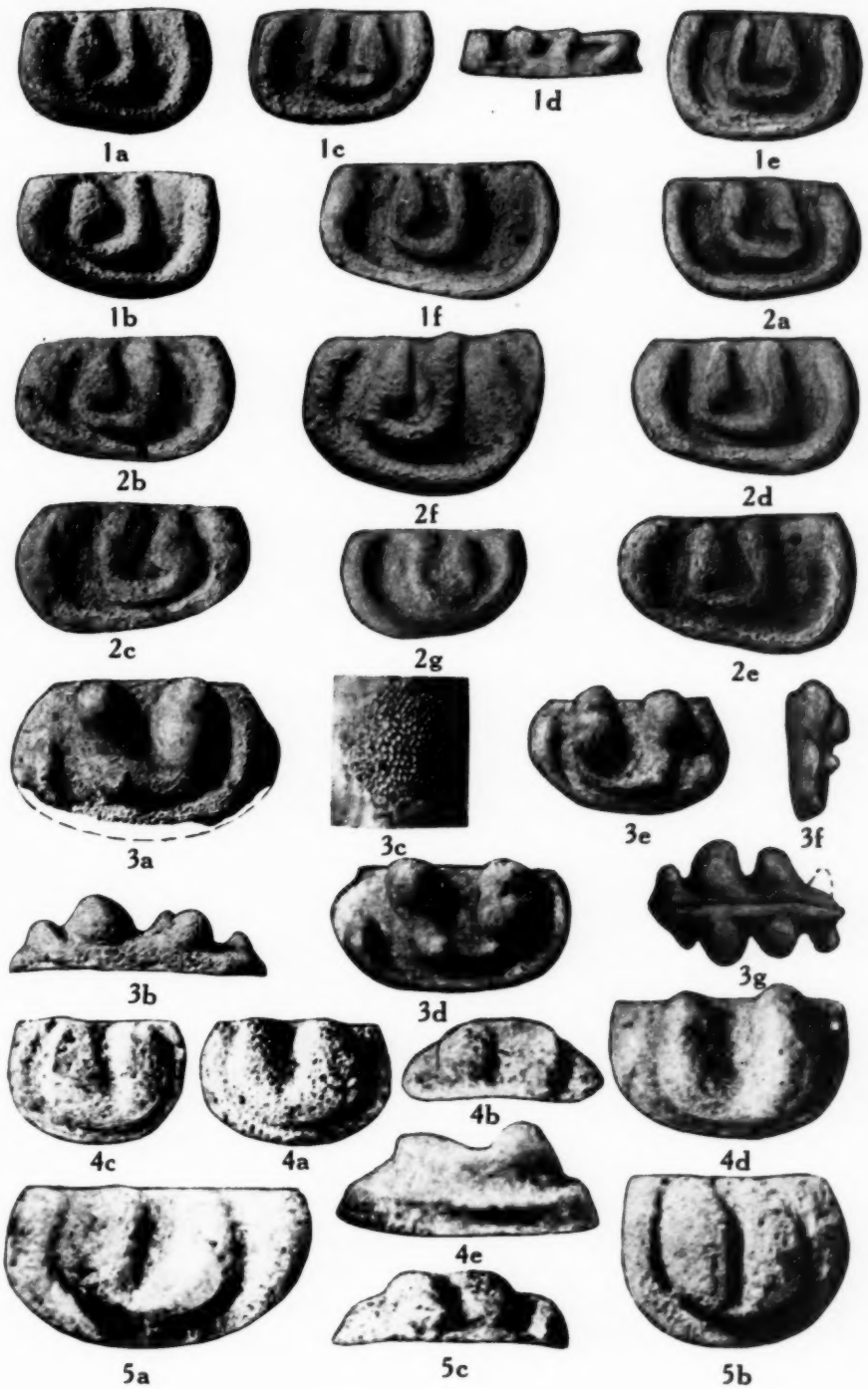
FIGS. *1a-f—Bollia sagittaformis* Swartz, n. sp. *1a*, Squeeze from holotype, an external mold of a left valve, ×15. *1b*, Squeeze from external mold of a left valve, ×15, showing some of the minute, distant surface pits. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. *1c, d*, Side and dorsal views of squeeze from external mold of a somewhat distorted right valve, ×15. From slab of Shriver chert, collected by J. B. Payne near Altoona, Pa., 1918. *1e*, Testiferous right valve, ×15. 23 feet below top of exposed Shriver chert, Mount Rock, Lewistown, Pa. *1f*, Squeeze from external mold of elongate variety, ×15. 62 to 67 feet above base of Shriver chert, Mount Rock, Lewistown, Pa. (p. 574)

2a–g—Bollia burgeneri Swartz, n. sp. *2a, b*, Side views of squeezes from syntypes, external molds of a right and left valve, ×15. *2c*, Squeeze from external mold of a slightly more elongate right valve, ×15. 70 feet above base of Shriver chert, Mount Rock, Lewistown, Pa. *2d, e*, Squeezes from external molds of an average sized and a more elongate left valve, ×15. 63 and 59 feet above base of Shriver chert, Mount Rock, Lewistown, Pa. *2f*, Squeeze from external mold of a left valve, preserving the minute surface pits, ×15. *2g*, Internal mold of a right valve, showing the impressions of the ridges, ×15. From slab of Shriver chert, collected by J. B. Payne near Altoona, Pa., 1918. (p. 575)

3a–g—Bollia americana var. *zygocornis* Swartz, n. var. *3a–c*, Side and dorsal views of squeeze from holotype, the external mold of a right valve, ×15, and detail of the surface of the anterior knob of the inner ridge, ×45. Upper half of Shriver chert, east side of Pine Creek, between Avis and Jersey Shore, Pa. *3d, e*, Side views of internal molds of a right and a left valve, ×15. *3f*, Posterior view of the squeeze in *3e*, unfortunately reversed in printing, ×15. *Dalmanites* bed at top of exposed Shriver chert, Mount Rock, Lewistown, Pa. *3g*, Squeeze from mold of dorsal part of a carapace, ×15. The valves are a little displaced with respect to one another. 90 to 110 feet above base of Shriver chert. Hollidaysburg, Pa. (p. 575)

4a–e—Bollia cristata Swartz, n. sp. *4a, b*, Side and dorsal views of squeeze from the holotype, an external mold of a right valve, ×22. Upper half of Shriver chert, east side of Pine Creek, between Avis and Jersey Shore, Pa. *4c*, Squeeze from external mold of a right valve, ×22. *4d, e*, Side and ventral views of internal mold of a large right valve, ×22, showing sag in ventral part of impression of the inner ridge. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. (p. 576)

5a–c—Bollia ungula Jones. *5a*, Squeeze from external mold of elongate left valve, ×22. *5b, c*, Side and dorsal views of squeeze from external mold of a shortened left valve, ×22. Buff Onondaga (?) calcareous shale, eastern outskirts of New Bloomfield, Pa. (p. 577)



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ture suggestive of *Beecherella*; but this region is quite smooth in most of the material.

Occurrence.—Common 55 feet above base of Shriver at Hollidaysburg, Pa.; common 59–75 feet above base of Shriver at Lewistown, Pa.; common to abundant in the *Metaplasia plicata* zone of the middle part of the Shriver at Curtin, Pa.

Family BAIRDIIDAE Sars

Genus TUBULIBAIRDIA Swartz, n. gen.

Genotype *Tubulibairdia tubulifera* Swartz, n. sp.

Carapace subovoid in side view, the posterior margin obtusely angulated; strongly inequivalved, the left valve the larger, overlapping the right along the free margins, and projecting above it dorsally. Actual hinge margin straight, apparently without specialized hinge structures. Carapace smooth externally, but pierced by coarse pores which open on the internal surface.

Relationships.—The characters of the hinge, the general shape of the carapace, and the inequality of the valves, suggest close relationship to *Bairdia;* but the coarse pores opening on the interior provide an important distinguishing character. No such pores are known in the species of *Bairdia* which have been so well described and figured by Kellett (33) and Van Veen (34).

TUBULIBAIRDIA TUBULIFERA Swartz, n. sp.

Plate 89, figures 2*a–r*

Carapace inequivalved, left valve larger than right; subovoid in side view; dorsal and ventral margins somewhat convex; anterior end rounded; posterior margin obtusely angulated; greatest height behind middle. In the large left valve there is a flattened cardinal area which slopes to the hinge; the hinge margin is long and straight, the internal molds showing well marked cardinal angles; the cardinal surface is thickened flat, apparently without ridges or grooves, judging from the internal molds. The specimens observed are internal and external molds of separated valves, so that details of marginal overlap are not clear; however, the ventral margin of the left valve has a broad extension, which evidently laps over the margin of the right valve.

Valves strongly convex, greatest convexity well behind the middle. Surface smooth, without lobes, sulci, or fine ornamentation. The right valve is about as long as the left, but lacks the umbonal swelling, and thus is not as high.

Internal molds of both valves bear strong spine-like projections, representing coarse tubular pores which open on the internal surface of the valves, but do not reach the exterior. These are usually widely separated, and irregularly arranged over the surfaces of the internal molds; but do not occur on the flattened area bordering the hinge of the left valve, or near the free edges, where the valves are thinned to accommodate the marginal overlap.

The dimensions of an average left valve are: length, 1.40 mm., height 0.98 mm., maximum convexity 0.68 mm. Right valve: length 1.40 mm., height 0.88 mm., maximum convexity 0.64 mm. The largest tubules are about 0.04 mm. in diameter.

Occurrence.—Common in the middle and upper parts of the Shriver in the sections studied.

Genus PARAHEALDIA Coryell and Cuskley

PARAHEALDIA (?) CENTRALIS Swartz, n. sp.

Plate 89, figures 3*a*, *b*

Carapace small, subovoid to subreniform in side view; dorsal margin convex, ventral margin nearly straight; ends rounded; greatest height about at or just in front of middle. Hingement and overlap unknown.

Surface of valve moderately convex, somewhat flattened toward the middle of the valve, declining more abruptly to the posterior than to the anterior and other margins. There is a fairly deep, rounded depression near the middle of the valve. At the summit of the posterior declivity are two small blunt spines or nodes.

The largest valve observed measures: length 0.51 mm., height 0.35 mm., convexity 0.14 mm.

Relationships.—The species has a median depression and two terminal nodes or spines comparable to those of *Parahealdia pecorella* Coryell and Cuskley and *P. ovata* Coryell and Cuskley (25a). The dorsal margin is more convex, and there is a median pit rather than a dorso-median sulcus as in those species. Coryell and Cuskley placed *Parahealdia* in the family Primitiidae; but the species here described, at least, does not belong in that family, as is shown by the strongly convex dorsal margin. At the same time, the median pit or sulcus is, of course, an abnormal feature for the family Bairdiidae.

Occurrence.—Rare in middle part of Shriver chert, Curtin, Pa.

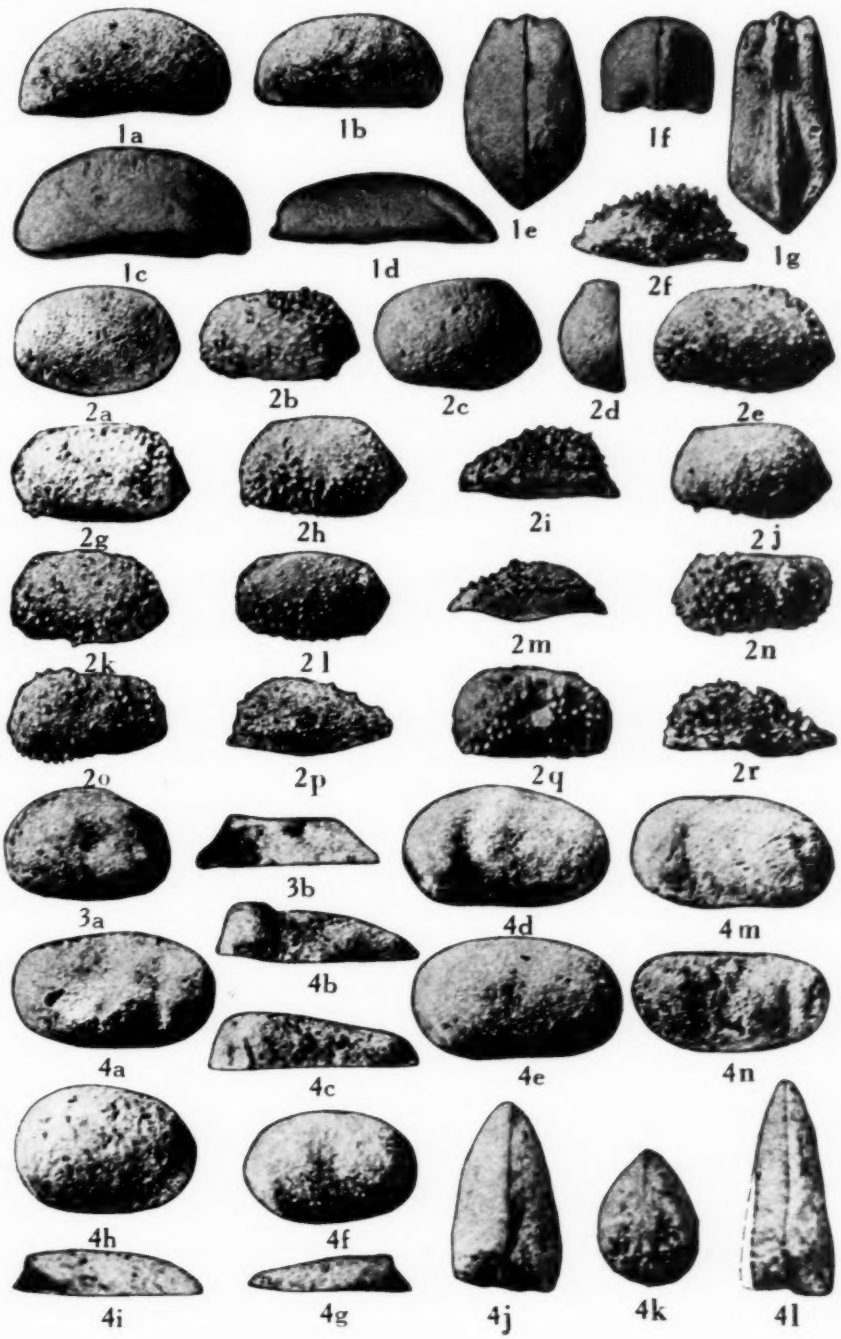
EXPLANATION OF PLATE 89

FIGS. *1a–g*—*Acanthoscapha pentagonalis* Swartz, n. sp. *1a, b*, Side view of squeeze from external mold, and side view of internal mold of holotype, the molds of a right valve, ×15. The impression of the muscle scar can be seen just below and slightly in front of the middle of the internal mold. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. *1c, d*, Side and ventral views of squeeze from external mold of left valve, ×15. *1e, f*, Dorsal and anterior views of squeeze from external mold of dorsal part of a thick, short carapace, ×15. 59 feet above base of Shriver chert, Mount Rock, Lewistown, Pa. *1g*, Squeeze from external mold of ventral part of a carapace, ×15. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. (p. 579)

2a–r—*Tubulibairdia tubulifera* Swartz, n. gen. and n. sp. *2a, b*, Side views of squeeze from external mold, and of internal mold of holotype, representing a left valve, ×15. *2c, d*, Side and posterior views of squeeze from external mold of a left valve, ×15, showing the flattened area adjacent to the hinge. *2e–m*, Side views of internal molds of left valves, with ventral views of the specimens shown in *2e, h*, and *l*, ×15. These specimens show some variations in size, shape, and in the character and arrangement of the spines representing the internal tubules. Note the flattened posterior angulations, and the relatively straight dorsal margins of these internal molds. *2n–r*, Side views of internal molds of right valves, with ventral views of the specimens shown in *2o* and *q*, ×15. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. (p. 581)

3a, b—*Parahealdia* (?) *centralis* Swartz, n. sp., side and dorsal views of the holotype, the internal mold of a left valve, ×45, showing the median pit and the two posterior nodes or spines. *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. (p. 581)

4a–n—*Cavellina paraquaesita* Swartz, n. sp. *4a–c*, Side and dorsal views of the holotype, an internal mold of a female left valve, ×22, showing impressions of the posterior internal excavation and of the dorso-median internal ridge; and dorsal view of squeeze from the imperfect corresponding external mold, ×22, showing little external reflection of the internal structures. *4d*, Internal mold of a typical female right valve, ×22. *4e*, Internal mold of a large male right valve, ×22. *4f, g*, Side and dorsal views of internal mold of male right valve, ×22. *4h, i*, Side and ventral views of squeeze from external mold of relatively short male right valve, ×22. Note that the internal dorso-median low ridge is not reflected externally, although the impression of this ridge is well shown in *4e–g*, *Metaplasia plicata* zone of middle part of Shriver chert, Curtin, Pa. *4j, k*, Dorsal and posterior views of squeezes from external molds of thick, presumably female carapaces, ×22. In the second specimen, which seems to be undistorted, the right valve slightly overlaps the left. *4l*, Dorsal view of squeeze from external mold of a thinner, presumably male carapace, ×22. *4m, n*, Internal molds of female right and left valves, ×22, the anterior end of the second specimen being abnormal in shape. 90 to 110 feet above base of Shriver chert, Hollidaysburg, Pa. (p. 583)



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Family Cytherellidae Sars

Genus Cavellina Coryell

Cavellina paraquaesita Swartz, n. sp.

Plate 89, figures 4*a–n*

Carapace wedge-shaped in dorsal view, the posterior end truncated, the sides gently convex; subovate to subelliptical in side view, the dorsal margin a little more convex than the ventral, the posterior end blunter than the anterior, the greatest height posterior to the middle; subovate in posterior view, the greatest thickness below the middle. The right valve seems to lap slightly upon the left valve; but the details are not clear from the material studied, and much of the apparent overlap may be due to squeezing.

Surface of valve smooth; moderately convex, sharply deflected near the posterior margin, generally with a low ridge-like swelling at the top of the deflection. There is sometimes a very shallow, undefined, scarcely discernible depression at about the middle of the dorsal half.

The specimens referred to this species fall into two groups, the second group evidently comprising productive females. The individuals of the latter group are somewhat larger than the others, and are somewhat thicker near the posterior end, although the external differences are not very pronounced. Internally, the posterior quarter of the valve is deeply excavated, the depression being bounded anteriorly by a low vertical ridge-like thickening, strongest near the ventral margin. In internal molds, the excavation is represented by a strong swelling, which is absent in the males, and presumably in the immature females. The internal molds of both males and females exhibit broad fairly well defined vertical depressions at about the middle of the dorsal half, evidently representing muscle thickenings on the interiors of the valves.

The measurements of an internal mold of a large male right valve are: length 1.24 mm., height 0.74 mm., convexity 0.30 mm. Those of an internal mold of a large female right valve are: length 1.24 mm.; height 0.76 mm., convexity in front of posterior swelling 0.37 mm., convexity at posterior swelling 0.41 mm.

Relationships.—The species is very close to the Lower Devonian *Cytherella quaesita* Roth (35), but the dorsal margin is more convex, and the external dorso-median depression is nearly obsolete. It is also related to the Silurian *Cytherella smithii* Jones, but, as illustrated by Bonnema (36), the males of the latter species are oblong in dorsal view, and are more regularly elliptical in side view.

The occurrence of dimorphism in Paleozoic cytherellids seems to have been first described by Bonnema (36a), who in 1933 proposed the generic name *Eocytherella* for *Cytherella smithii* Jones and *C. quaesita* Roth, stating that the females of *C. smithii* have a simple posterior internal depression (37). The dimorphism of *Cavellina* was subsequently described by Kellett (60), who credits the recognition of the dimorphism of Carboniferous species of this genus to unpublished studies of H. L. Geis. It seems doubtful to the writer that *Eocytherella* Bonnema can be satisfactorily distinguished from *Cavellina* as emended by Kellett, although in *Cavellina* the posterior female cavity is said to be separated off by a vertical ridge, rather than by excavation.

Occurrence.—Common, *Metaplasia plicata* zone of middle part, and common in upper part of Shriver chert, Curtin, Pa.; fairly common, 90 to 100 feet above base of Shriver, Hollidaysburg, Pa.

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1. E. O. Ulrich and R. S. Bassler, Ostracoda, *Maryland Geol. Survey, Lower Devonian*, pp. 515–540, pls. 95–98. (*a*) p. 525, pl. 96, figs. 13–15, 1913.
2. F. M. Swartz, Revision of the ostracode family Thlipsuridae, with descriptions of

new species from the Lower Devonian of Pennsylvania: *Jour. Paleontology*, vol. 6, no. 1, pp. 36–58, pls. 10, 11, 1932.

3. Since this paper was submitted for publication, the writer has corresponded with Dr. A. S. Warthin concerning the ideas on classification expressed here. Dr. Warthin has been interested in this matter not only because of his own investigations, but also because he is preparing the Devonian Ostracoda section of the new Card Catalogue. He has independently reached conclusions which to a considerable extent parallel those presented in this paper. There are, of course, inevitable differences in opinion, and some of these are discussed in footnotes at appropriate places. To a considerable extent these differences concern genera whose relations admittedly need further clarification.
4. SWARTZ, F. M., The Helderberg group of parts of West Virginia and Virginia: *U. S. Geol. Survey, Prof. Paper* 158, pp. 47, 48, 63, 1929.
5. ULRICH, E. O., and BASSLER, R. S., Paleozoic Ostracoda, their morphology, classification and occurrence: *Maryland Geol. Survey, Silurian*, pp. 271–391, 1923; Ostracoda, idem, pp. 500–704, pls. 36–65. (*a*) p. 300. (*b*) p. 297. (*c*) p. 310. (*d*) pp. 312–314; Ostracoda, idem, pp. 600–700 pls. 57–62 (*e*) pp. 528, 529. (*f*) pp. 531, 532. (*g*) pp. 283–285. (*h*) p. 273, fig. 11, 3. (*i*) p. 504, pl. 36, fig. 20. (*j*) p. 504, pl. 36, fig. 24.
6. ——— New American Paleozoic Ostracoda; Preliminary revision of the Beyrichiidae, with descriptions of new genera: *U. S. Nat. Mus., Proc.* 35, pp. 277–304, figs. 1–61, pls. 37–44. (*a*) p. 283. (*b*) pp. 315–317. (*c*) pp. 280–282, 1908.
7. BASSLER, R. S., and KELLETT, BETTY, Bibliographic Index of Paleozoic Ostracoda: *Geol. Soc. Am., Special Papers*, no. 1, pp. 438–460. (*a*) pp. 26–29. (*b*) p. 5, 1935.
8. SWARTZ, F. M., Dimorphism and orientation in ostracodes of the family Kloedenellidae from the Silurian of Pennsylvania: *Jour. Paleontology*, vol. 7, pp. 231–260, pls. 28–30. (*a*) pp. 234–236, 1933.
9. For bibliographies see reference 7.
10. Warthin feels that the dorsal spines and submedian pit of *Dicranella bicornis* ally this genus very closely with *Paraechmina*. He also thinks that *Paraechmina* belongs with the *Bollia-Jonesites* group, and suggests that all of these genera belong in the Drepanellidae. On the other hand, he is inclined to place *Aechmina* in the Primitiidae. The writer believes it probable that many species of *Aechmina*, including the *A. bigeneris* and *A. spinoterminata* of this paper, are actually derivatives of *Paraechmina*. The relations of the latter genus, and of the Silurian and Devonian species of *Aechmina*, to the late Ordovician *A. richmondensis* Ulrich and Bassler, need clarification. As stated elsewhere, if this species represents the ancestral stock from which *Paraechmina* and *Aechmina* were derived, then these genera would apparently have their roots somewhere in the Leperditellidae. If not, they may well have been derived from *Dicranella*.
11. MUNTHE, H., HEDE, J. E., and VON POST, L., Beskrivning till kartbladet hemse.: *Sveriges Geologiska Undersökning*, ser. Aa, no. 164, p. 18, 1927.
12. MCCOY, F. A. *A synopsis of the Silurian fossils of Ireland*, Dublin, p. 58 1846.
13. Warthin believes that *Kirkbyella* Coryell and Booth is definitely allied to the Kirkbyidae by its complex ornamentation and hinge grooving, even though it has a well developed primitiid sulcus. He further believes that *Halliella* and *Jonesites*, and possibly *Pyxiprimitia*, are so close to *Kirkbyella* that all of these genera must be placed together, possibly as a subfamily under the Kirkbyidae. Placing greater emphasis upon the sulcus, the writer prefers to leave them in the Primitiidae, at least until a better chain of connecting species is discovered.
14. ULRICH and BASSLER express some doubt about the inclusion of this genus among the Ostracoda.
15. Warthin believes that the genera *Allostraca* and *Paracythere* belong in the Hollinidae and not in the Kirkbyidae. The frill of *Allostraca* suggests such a relationship; but doubt is raised by the subcentral pits and markedly subrhomboidal form, especially as seen in *Paracythere*.
16. Because of the central position of the large node, Warthin doubts that *N. binsenbachensis* is related to *Hollina*. He would prefer tentatively to place *Neochilina* in the Beyrichiidae.
17. KAY, G. M., Mohawkian Ostracoda; Species common to Trenton faunules from the Hull and Decorah formations: *Jour. Paleontology*, vol. 8, pp. 328–343, 1934.
18. In the opinion of G. M. Kay the closely related *Clenobolbina crassa* Ulrich is not only congeneric but actually synonymous ous with *Dilobella typa* Ulrich. (Personal communication.)
19. The genera *Lindsayella*, *Cornulina*, and *Aechminaria*, recently proposed by H. N. Coryell and Marjorie Williamson (*Am. Museum Novitiates*, No. 870, July 6, 1926, p. 1, 2, 5) are closely related to *Paraechmina*. The species placed in these genera clearly belong in the Aechminidae.

13 15 16 18

20. ALEXANDER, C. I., Shell structure of the ostracode genus *Cytheropteron*, and fossil species from the Cretaceous of Texas: *Jour. Paleontology*, vol. 7, no. 2, p. 202. (*a*) pp. 202, 203. (*b*) p. 182, pl. 25, figs. 5, 6, 1933.
21. BONNEMA, J. H., Uber die aufstellung der palaozoischen Ostracoden: *Zeitsch. f. Geschiebeforschung*, vol. 10, pt. 2, 1934.
22. H. L. GEIS, Some ostracodes from the Salem limestone, Mississippian, of Indiana: *Jour. Paleontology*, vol. 6, p. 151, pl. 22, 1932.
23. HARRIS, R. W., Description of ostracodes and conodonts: *Oklahoma Geol. Survey*, Bull. 55, pp. 87, 88, pl. 5, figs. 4*a*, *b*, 1931.
24. CORYELL H. N., and BOOTH, R. T., Pennsylvanian Ostracoda; a continuation of the study of the Ostracode fauna from the Wayland shale, Graham, Tex.: *Am. Midland Naturalist*, vol. 14, no. 3, p. 262, pl. 3, fig. 7. (*Kirkbyella typa*), 1933.
25. CORYELL, H. N., and CUSKLEY, V. A., Some new Ostracodes from the "White Mound" section of the Haragan shale, Murray County, Okla: *Am. Mus. Novitiates*, no. 748, p. 2, figs. 1, 2. (*a*) pp. 3, 4, figs. 17, 18 (*Kirkbyella verticalis*), 1934.
26. JONES T. R., and HOLL, H. B., Notes on the Paleozoic bivalved Entomostraca, No. 6: *Ann. and Mag Nat. Hist.*, ser. 3, vol. 16, pp. 418, 419, pl. 13, figs. 6*a*, *b*, and 6*c*, *d*, 1865.
27. ULRICH, E. O., New American Paleozoic Ostracoda: *Jour. Cincinnati Soc. Nat. Hist.*, vol. 19, p. 183, pl. 8, fig. 12, 1900.
28. ——— New and little known American Paleozoic Ostracoda: *Jour. Cincinnati Soc. Nat. Hist.*, vol. 13, p. 100, pl. 7, fig. 6, 1891.
29. KUMMEROW, E., Beiträge zur kenntnis der ostracoden und phyllocariden aus nordischen Diluvialgeschieben: *Jahrb. Preuss Geol. Landesanstalt Abh.*, für 1923, pp. 431, 432, pl. 21, fig. 9, 1924.
30. The writer has recently obtained species of *Parabolbina* from the Keyser limestone in Pennsylvania and the Manlius limestone in eastern New York. In both cases, there is an association of frilled and non-frilled forms, suggesting that the frill is a dimorphic structure as in *Hollinella*.
31. JONES, T. R., Some Devonian and Silurian Ostracoda from North America: *Quart. Jour. Geol. Soc. London*, vol. 46, p. 540, pl. 20, fig. 5. (*a*) p. 540, pl. 20, fig. 12, 1890.
32. A number of Carboniferous species with two dorsal knobs have been referred to the genus *Ulrichia*. The entire surface within the submarginal flange, including the surfaces of the knobs, is reticulate. This fact, together with the occurrence of specialized hinge structures and evident relationship to species of *Amphisites*, indicates that the Carboniferous forms are not related to *Ulrichia* or the Drepanellidae, but are a separate development in the Kirkbyidae. An excellent analysis of the Carboniferous species has been published by Kellett, who stated: "It is possible that this well defined Carboniferous group of Kirkbyidae is not congeneric with the type, *U. conradi* Jones." The writer proposes to place the Carboniferous species in the new genus *Kellettina*, and Kellett's analysis is quoted in full.

Genus KELLETTINA Swartz, n. gen.

"Straight-hinged, elongate Kirkbyidae with angular cardinal extremities, the anterior usually the more acute. Left valve having a slight inside beveling, and overlapping the beveled outside edge of the right. Hingement consists of a more or less prominent ridge on the left valve and a groove on the right, with the cardinal teeth on the left valve and the corresponding sockets on the right valve, which are characteristic of the family (i.e. Kirkbyidae), sometimes well developed. Two large and prominent nodes located on the upper half of the valve are the distinguishing features of the genus, (as compared to other Kirkbyiidae) the anterior one the larger. Pit located near the antero-ventral corner of the posterior node. Two or more well developed flanges present. Surface recticulated." (B. Kellett, Ostracodes of the Upper Pennsylvanian and the Lower Permian of Kansas: *Jour. Paleontology*, vol. 7, p. 92; see pl. 15, figs. 33–40, 42, 1933.) In *Kellettina* the marginal rim tends to be narrower than in *Ulrichia*, the surface is reticulated rather than pitted, and the reticulation extends over the dorsal knobs.

Genotype: *Ulrichia robusta* Kellett.

Relationships: In addition to *U. robusta*, the species *U. binoda* Roth and Skinner, and *U. monotosa* Knight clearly belong in *Kellettina* and to the Kirkbyiidae. The Kirkbyan relationships of *Kelletina montosa* were recognized by Knight in 1928. (J. B. Knight, Some Pennsylvania ostracodes from the Henrietta formation of eastern Missouri: *Jour. Paleontology*, vol. 2, pp. 318–336, 1928.

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39. The writer has not obtained McCoy's volume. However, McCoy's discussion of *Beyrichia* is quoted rather fully by Bell and Forbes in an appendix to their English edition of H. Burmeister, *The Organization of Trilobites* pp. 124, 125, 1846. According to this quotation, McCoy points out that the unsymmetrical position of the lobes of his specimens of *Agnostus* (*Battus*) *tuberculatus* Kloeden, from Ireland, shows that they must be the two valves of an entomostracous shell. He therefore supports the similar view concerning continental specimens of Kloeden's species, advanced a short time earlier by Beyrich, and names his new genus after that author in recognition of penetration. McCoy further states: "The species I propose naming after its original discoverer, *Beyrichia Kloedeni*." It seems clear, especially from the latter remark, that *Beyrichia tuberculatus* (Kloeden) not only can, but must be regarded as the genotype of *Beyrichia*.

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LOWER PERMIAN FUSULINIDS FROM SUMATRA

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ABSTRACT

One new species each of *Schwagerina* Möller and *Pseudoschwagerina* Dunbar and Skinner from the so-called "Productus limestone" of Telok Gedang, Sumatra, are here referred to the Lower Permian.

Several reports have been published in recent years concerning the fauna of the so-called "Productus limestone" of Telok Gedang, central Sumatra. This fauna has been regarded as Upper Permian in age by some and as Upper Carboniferous in age by others. The productid-bearing beds at Telok Gedang are about 100 feet thick, are composed of a complex of dark-gray limestones, clay slates, and siliceous shales, and are overlain by the plant-bearing beds of Soengi Garing. The age of the plant beds of Soengi Garing has also been a subject of some dispute.

In 1922 Meyer (4) considered the brachiopod fauna to indicate an Upper Permian age for the productid-bearing beds. The flora of the overlying Soengi Garing plant beds was later studied by Jongmans and Gothan (3), who referred it to the Upper Carboniferous. In 1923 Tobler (6) discussed the productid-bearing beds under the Permian, but he did not state the portion of the Permian to which he considered these beds referable. In 1929 Ozawa (5) examined thin sections of limestone in the Museum of Natural History of Basel collected by the late Dr. August Tobler from Telok Gedang. Ozawa identified a form as *Schwagerina princeps* (Ehrenberg) and, mainly on the basis of this identification, referred the Telok Gedang marine beds to the Upper Carboniferous. He suggested that these beds should be correlated with the marine strata below the coal bearing complex of north China and Korea.

Dr. Rolf Rutsch recently sent me a number of thin sections and two hand specimens of a very dark-gray limestone collected by Tobler which are labeled "Telok Gedang A, laag d (Merangin)," Sumatra. This material contains two species of fusulinids, one of which was that identified by Ozawa as *Schwagerina princeps* and the other of which represents an undescribed species of *Schwagerina*, s.s. The former of these species is referable to the genus *Pseudoschwagerina* Dunbar and Skinner. I want to take this opportunity to express my sincere thanks to Doctor Rutsch for the opportunity to study this material and for permission to use it in this publication.

Fusulinids of Middle Permian age

have been described or reported from numerous localities in central and western Sumatra. Permian fusulinids have been reported also from several localities in northern Sumatra. However, very few occurrences have been recorded of fusulinids from Sumatra that are not definitely younger than the lower part of the Middle Permian. The forms that I am describing below as *Pseudoschwagerina meranginensis* and *Schwagerina rutschi* clearly indicate a Lower Permian age. Fusulinids of the general type of *S. rutschi*, when considered by themselves, are not very good index forms for detailed correlations over wide areas, but *S. rutschi* supports the age determination of the productid-bearing beds based primarily on *P. meranginensis*. Fusulinids closely similar to *P. meranginensis* and generally referred to *Schwagerina princeps* (Ehrenberg) are very widespread in Europe and Asia, and they occur in strata now generally referred to the Lower Permian. This type of fusulinid is very abundant in the Chuanshan limestone of southern China, the Taiyuan series of northern China, the Lower Permian of northern and eastern Russia, and the Lower Permian of northern Carniola. Rather closely similar forms are also known from the Lower Permian of America.

In 1875 Verbeek (7) reported fusulinids from the lower unit of the "Carboniferous or Permian" of the Padang Highlands of western Sumatra. This lower unit is composed of clay slates and siliceous shales with intercalated limestones, and it may be equivalent in age to the beds at Telok Gedang from which the specimens I am studying were collected. The upper unit of Verbeek's "Carboniferous or Permian" of the Padang Highlands contains the well-known Middle Permian fusulinid fauna of Guguk Bulat and Bukit Bessi.

All of the material studied in the preparation of this report is in the Museum of Natural History, Basel.

SYSTEMATIC DESCRIPTIONS

SCHWAGERINA RUTSCHI Thompson, n. sp.
Figures 6–13

Shell rather large, fusiform; poles sharply pointed; lateral slopes moderately low, uniform. Mature forms of five and one-half to six volutions; about 7 mm. long, 3 mm. wide. Form ratio, 1:1.6 for the second volution, 1:2 for the fourth volution, 1:2.3 for the sixth volution. As can be seen from these measurements, the shell is short, robust for young individuals and the poles become extended with growth.

Septa very thin, composed of tectum and a lighter, very thin layer on the posterior side. Near tunnel lower portions of septa coated with thick deposits of dense calcite, apparently continuations of the chomata. Septal count of a number of typical specimens gives 10 to 13 for first volution, 15 to 19 for second, 17 to 25 for third, 24 to 33 for fourth, 24 to 36 for fifth, 26 to 29 for sixth. Average septal count of same volutions for six typical specimens gives 12, 18, 22, 27, 29, and 29, respectively. Septa highly, narrowly fluted in polar regions, but fluting is lower, somewhat more broadly spaced near center of shell.

Proloculum rather large; inside diameter 120 to 160 microns, average about 140 microns. Shell expands at a very uniform rate; average heights of first six volutions for seven typical specimens, 35, 115, 170, 255, 310, and 350 microns.

Spirotheca thick, composed of very thin tectum and well-developed keriotheca. Alveoli very clear throughout thickness of keriotheca; near top of keriotheca alveoli very fine, becoming coarser toward base; at least four alveoli near top form only one near lower surface of spirotheca. Alveoli appear to continue to upper surface of outermost volution, and opening to the outside through a slightly more dense outer portion. It is not at all certain, however, that the outer portion of the spirotheca of this outer volution has not been removed during fossilization. It should be mentioned that the alveoli extend completely through the spirotheca of the next to the last volution of several of the thinnest sections I am studying, but even here the tectum may have been removed during fossilization. Average thicknesses for spirotheca of first six volutions of five typical specimens, 17, 34, 52, 78, 104, and 130 microns.

Tunnel very narrow, almost circular in cross section in inner two or three volutions; from fifth to sixth volutions becoming noticeably wider; in sixth volution the tunnel angle measures 30° to 45°. Chomata in form of low asymmetrical ridges in inner two to three volutions; in the outer volutions more or less irregular deposits spread over lower portion of septa and upper surface of spirotheca. Line of intersection of tunnel with axial sections irregular throughout the shell.

Two distinct layers can be recognized in the keriotheca of this species. The upper layer has very fine alveoli, and it makes up only about one-fifth of the entire thickness of the keriotheca. The lower layer has unusually coarse alveoli and it makes up the remaining four-fifths of the keriotheca. The line of division of these two layers is rather sharp. About four alveoli of the upper layer cover the same area as one alveolus of the lower layer. The walls of the alveoli do not seem to fuse, as has often been illustrated and described by students of the fusulinids, but they probably hang down so that even the finest alveoli at the top of the keriotheca are open toward the base of the spirotheca. Sagittal and axial sections cut the walls of the more or less cylindrical tubes of the alveoli so that they appear to fuse downward to form the heavier dark lines of the lower part of the keriotheca. Gubler (2) has recently discussed at some length the secretion and structure of the spirotheca of the members of the subfamily Schwagerininae, and has expressed the belief that the spirotheca is formed by the cementation of prisms and pellets of calcite and that the dark lines of the alveoli are the cementing material which holds the solid wall together. It seems to me that the spirotheca of these forms is in reality of a honeycomb nature and that the dark lines are the primary portion of the keriotheca. As explained above, the alveoli of the outer volution, and in some specimens the next to last volution, seem to pass completely through the spirotheca but the tectum of these volutions may have been removed during fossilization. It is not here considered that these observations prove the porosity of the spirotheca of the fusulinids.

This species is somewhat intermediate between typical *Triticites* Girty and typical *Schwagerina* Möller, but it seems to be more closely related to the type of the latter genus, *S. princeps* (Ehrenberg), and hence I am referring it to *Schwagerina*.

The general development of this species is closely similar to that of *Schwagerina chinensis* (Ozawa) and *S. haydeni* (Ozawa) of the Lower Permian of Honan, China, and Nagato, Japan, respectively. *S. chinensis* is smaller, has a smaller form ratio, and fewer septa than *S. rutschi*. *S. haydeni* has a much smaller form ratio at maturity and the development of its inner volutions is different from that of the inner volutions of *S. rutschi*.

Occurrence.—Abundant in a dark-gray limestone at Telok Gedang, Sumatra, where it is associated with *Pseudoschwagerina meranginensis*.

PSEUDOSCHWAGERINA MERANGINENSIS
Thompson, n. sp.
Figures 1–5

Schwagerina princeps OZAWA, *1929*, Eclogae Geol. Helvetiae, vol. 22, pp. 51, 52.

Among the large number of sections from Telok Gedang sent to me by the Museum of Natural History of Basel there is only one specimen of the genus *Pseudoschwagerina*. The slide containing this specimen is labeled "*Schw. princeps*" and this undoubtedly is at least a part of the material on which Ozawa based his discussion of *Schwagerina princeps* from Telok Gedang. However, this section is not centered and it spread into many parts on covering. I have obtained a number of well centered sections and several random sections of this form from the same limestone samples from which Ozawa's sections were made. The largest specimens are composed of only six volutions and are relatively small, but most of them are of about the same size and probably represent mature individuals.

These Sumatran specimens resemble rather closely the inner six volutions of the form from Archangel, Russia, illustrated by Möller as *Schwagerina princeps* (Ehrenberg), and the specimens later referred to that species by Schwager, Schellwien, Yabe, Deprat, Lee, Ozawa, and others; and they may possibly be conspecific with a part of those forms. It seems to me that a number of species are represented within this group. Dunbar and Skinner (1) have shown that *Schwagerina princeps* (Ehrenberg) is quite distinct from the forms generally referred to that species and hence the forms referred to *S. princeps* by Möller and others, as well as the form I am studying, are without valid specific names.

Shell of medium size for genus, short, subspherical at maturity, highly inflated. Specimens of six volutions 4 mm. long, 3.4 mm. wide. Form ratio about 1:1.5 for second volution, 1:2.2 for fourth, 1:1.2 for sixth. Shell of young individuals roughly fusiform; with growth shell becomes more broadly ellipsoidal; at maturity essentially spherical.

Septa very thin, composed of downward extension of tectum of spirotheca and a very thin lighter layer on the posterior side. Septa rather closely spaced in innermost volutions but in the outer very highly expanded portion of the shell very widely spaced. Septal count for a typical specimen of six volutions, 9, 12, 13, 16, 15, and 15. In outer two volutions of specimens of six volutions lowermost portion of septa rather broadly fluted but middle and upper portions of septa essentially unfluted. In extreme polar regions septa slightly more highly fluted.

Proloculum spherical, very small; inside diameter 35 to 45 microns. Juvenarium very tightly coiled, composed of about four volutions. Beyond juvenarium shell becomes very highly inflated. Average heights of first six volutions of four typical specimens, about 26, 43, 66, 140, 495, and 755 microns. Axes of coiling of all volutions essentially parallel.

Spirotheca thin, composed of tectum and a coarsely alveolate keriotheca; increasing in thickness slowly in inner four volutions, very rapidly in outer two volutions. Average thicknesses for spirotheca of first six volutions, 3.5, 8.7, 15, 25, 35, and 63 microns. Alveoli very coarse, in

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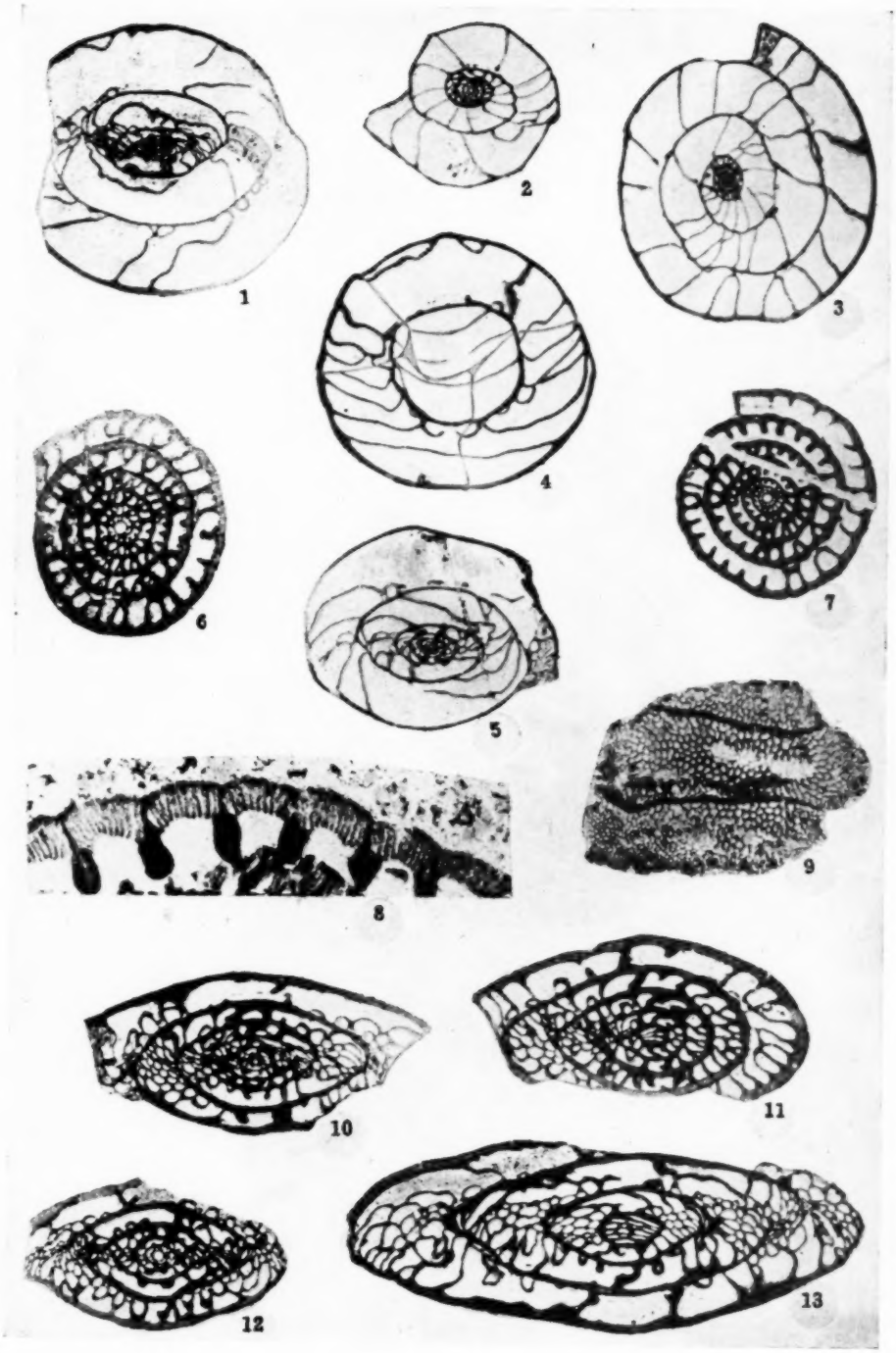
EXPLANATION OF FIGS. 1–13

FIGS. *1–5*—*Pseudoschwagerina meranginensis* Thompson, n. sp. *1*, *5*, Axial sections; 2, oblique section; *3*, sagittal section; *4*, tangential section. (p. 590)

6–13—*Schwagerina rutschi* Thompson, n. sp. *6*, *7*, Sagittal sections; *8*, enlarged portion of the spirotheca of the sixth volution of a sagittal section of a specimen of six volutions; *9*, enlarged portion of a tangential section which cuts the spirotheca of the fifth or sixth volution; *10*, *12*, axial sections; *11*, oblique section; and *13*, section tangential to the second volution. Unretouched photographs, ×10, except figures 8 and 9 which are magnified ×40. Lower Permian, Telok Gedang, Sumatra. (p. 588)



FIGS. 1–13

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sixth volution about 17 microns in diameter.

Tunnel low, wide, in fifth and sixth volutions about one-eighth as high as chambers. Tunnel angle 40° to 50° in fifth and sixth volutions. Chomata well developed in inner four volutions, only slightly asymmetrical. In outer two volutions chomata very feebly developed or absent.

Occurrence.—Rather abundant in a dark-gray limestone at Telok Gedang, Sumatra, where it is associated with *Schwagerina rutschi.*

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LICHADIAN TRILOBITES

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ABSTRACT

The classification of the group of trilobites formerly placed under the family Lichadidae is here revised in the light of the morphology and the evolution. The group is designated a superfamily, the Lichadacea, and divided into two families, the Lichadidae and the Trochuridae. The Lichadidae include the subfamilies Lichadinae, Tetralichadinae, Homolichadinae, and Gaspelichadinae; the Trochuridae, the subfamilies Trochurinae, Hemiarginae, Dicranopeltinae, and Platylichadinae. The genera are redescribed; 17 new genera are proposed. It is pointed out that the lichad glabella is composed of six segments, and is derived from a form with four pairs of lateral glabellar furrows. Studies of the geographic distribution indicate that the greatest evolution occurred in northern Europe and that there were two migrations to North America, one by way of northern Greenland.

INTRODUCTION

The following paper is the result of two years study conducted at the Museum of Comparative Zoology under the supervision of Prof. Percy E. Raymond. A large part of the information has been obtained from published descriptions of figures and genera. These data have been supplemented by the study of specimens in the collections of the Museum of Comparative Zoology.

Acknowledgments.—The writer wishes to acknowledge his appreciation of Professor Raymond's sympathetic aid and many valuable criticisms and suggestions. The writer is grateful to Miss Elsa Warburg for sending casts of the type specimens of *Amphilichas lineatus* and to Dr. Rudolph Ruedemann for permission to study specimens of *Arctinus boltoni* at the New York State Museum.

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MORPHOLOGY

The unusual glabellar lobation of lichadian trilobites has been discussed by Reed (1902) and Warburg (1925). The anterior glabellar furrows apparently are produced longitudinally in a posterior direction. These furrows, which I am calling the "longitudinal furrows," are well-incised and reach the occipital furrow in most lichads. There seems no basis for assuming, however, that the longitudinal furrows are simple extensions of the first lateral furrows, as Reed (1902, p. 6) has done; moreover, these furrows should not be confused with the dorsal furrows. They appear to be composite furrows formed by the migration of the appendifers into an anterior-posterior line. In some cases, as in *Dicranogmus* and *Richteria*, the first lateral furrows become obsolete, but the longitudinal furrows are well developed.

One or more pairs of lateral furrows are obsolete in all cases, resulting in composite lobes. According to the interpretation proposed by Reed, the lichad glabella is a modification of one with three lateral furrows and

five pairs of lobes in the glabella, including the occipital lobes. If this were true, the fusion of lobes by the obsolescence of lateral furrows would form bicomposite lobes where two lobes on each side are fused and tricomposite lobes where three are fused (terms proposed by Reed). Whether or not the glabella is to be considered as having five lobes depends upon the interpretation given the "occipital" lobes. If these lobes are morphologically basal lobes, and do not belong to the occipital segment, then the glabella is composed of six segments (including the occipital segment).

The writer considers the basal lobes true basal glabellar lobes, but Reed (1902, p. 65) is of the opinion that they are parts of the occipital segment, for the following reasons:

> The narrowness of the neck ring behind these lobes and its much greater width in the center, the bending-forward of the lateral portions of the occipital furrow in front of them, and the the non-continuation of this furrow onto that which marks off the occipital segment on the cheeks.

In all illustrations, and in all actual specimens seen by the writer, of genera that have no basal lobes, such as *Tetralichas* and related forms, it has been observed that the part of the occipital segment directly behind the lateral lobes is narrower than the middle part of the segment. This suggests that the occipital segment has been narrowed in this region by the backward crowding of the composite lateral lobes. On the fixed cheeks the occipital segment is only as wide as it is behind the lateral lobes. These facts suggest that crowding and consequent narrowing of the occipital segment occurs independently of the development of the basal lobes.

In all specimens of *Hoplolichoides* recently collected in Esthonia by Prof. P. E. Raymond, and now in the Museum of Comparative Zoology, it is obvious that the lobes in question are a part of the glabella. The occipital segment is distinctly separated from these lobes by a deep furrow, whereas the basal lobes are separated from the tricomposite lobes by a shallower depression and clearly belong to the lateral lobation. In no case does the occipital furrow divide and surround the basal lobes.

The writer agrees with Reed that the furrows limiting the basal lobes on the anterior side do not continue on to the fixed cheek, whereas the one which bounds the posterior side is continuous on the cheek. This further indicates that there has been a backward squeezing of the occipital segment behind the lateral glabellar lobes.

Reed (1902, p. 65) compares these lobes with the "occipital" lobes in *Proetus*. In all specimens of *Proetus* that I have examined these lobes appear to be true basal glabellar lobes for the same reasons here given in regard to the lichadian trilobites. I doubt that *Proetus* can be proved to possess "unquestioned occipital lobes."

The orthodox view that the glabella is composed of five segments, of which the occipital ring is the fifth, makes it necessary to consider that the basal lobes belong to the oc-

cipital segment instead of to the lateral glabellar lobes. If this is true there can be only three pairs of lateral glabellar furrows. In the Lichadacea the anterior furrows are the first pair, the second pair is obsolete, or in some cases represented by a mesial notch on the anterior bicomposite lobes, and the "middle" furrows are the third pair. The only valid reasoning, according to the orthodox view, is to consider that the occipital furrow has split at each side of the glabella, forming the "occipital" lobes.

There are other reasons for believing that the "occipital" lobes are true basal glabellar lobes. The dorsal furrows, where present, reach the occipital furrow outside the basal lobes. In all cases the basal lobes unite with the fourth glabellar lobes, if they unite with anything. This can be seen in *Hemiarges* and *Choneilobarges*. Also, in trilobites in general the basal lobes are the strongest and the most completely separated from the rest of the glabella, as, for example, in *Calymene*. Moreover, some trilobites clearly have four pairs of lateral furrows in the glabella.

Foerste (1920) has given a somewhat different interpretation of the lichadian glabellar lobation. He considers the basal lobes to belong to the glabella, but nevertheless derives the group from an hypothetical ancestor with three pairs of lateral furrows. As he points out, such an ancestor must have had an anterior lateral lobe considerably longer than the second lobe and a second lobe longer, in most cases, than the third. There is little reason to doubt, however, that the anterior lobe of lichadian trilobites is of a composite nature, for in such species as *Lichas ferrisi* (Weller), *Craspedarges scutalis* Reed, and *Trochurus geikei* (Nicholson and Etheridge) there is a distinct notch (or pit) on the longitudinal furrow about halfway between the first and third lateral furrows. This conclusion agrees with that of Reed (1902) and Warburg (1925).

The lichad glabella, then, is composed of six segments, and the ancestral form must have possessed four lateral furrows. Since the second lateral furrow is obsolete in all cases, or only indicated, we may have, besides bicomposite and tricomposite lobes, "quadricomposite" and "doubly bicomposite" lobes (terms proposed by the writer). Such forms as *Tetralichas*, *Terataspis*, and *Probolichas* have quadricomposite lobes. Doubly bicomposite lobes are seen in the Euarginae. Tricomposite lobes are characteristic of the Homolichadinae.

The lichadian glabellar lobation is undoubtedly closely connected with the development of the ventral appendages. Since no lichad, to the knowledge of the writer, has been found showing the appendages, the actual relationship can be made out by inference only. The mechanical advantages of the connection of the appendifers in a fore-and-aft line are not entirely clear. Raymond (1920, p. 65) has shown that the endobases of the coxopodites are modified as gnathites in the cephalic region, and as such they are intimately con-

nected with the development of the hypostoma and the mouth itself. According to Raymond,

> while the more anterior of the coxopodites are attached in front of the posterior tip of the hypostoma, the gnathites of *Triarthrus* bend backward so that all are behind the hypostoma. In *Calymene* and *Ceraurus*, two or three pairs of the gnathites are back of the hypostoma, and one or more pairs may be beside or under the hypostoma. In these genera the mouth is probably in front of the tip of the upper lip.

In some lichad genera, such as *Trochurus*, *Euarges*, *Craspedarges*, and *Conolichas*, there is a median depressed area immediately anterior to the occipital segment. This depression appears to be caused by a convergence of the glabellar furrows at this place; this phenomenon is especially noticeable in several species of *Trochurus*. It is possible that the posterior elongation of the hypostoma may have caused a concentration at this point of attachments for the cephalic appendages. Such crowding may also have caused a backward stretching of the endobases of the coxopodites, thus forcing their attachments into a fore-and-aft position and forming the longitudinal furrows. If the endobases functioned as masticating organs (gnathites), it appears logical to suppose that they were posterior to the mouth. Any posterior migration of the mouth would furnish a mechanism for the backward stretching of the anterior appendage attachments, and this tendency may have had a similar effect on the posterior attachments in some cases. The effect of the hypostoma in causing this migration may have been only secondary.

Two types of lichadian pygidia have been recognized that appear to be important in the classification of the group. The first is characterized by having two or three pairs of leaf-like ribs which occupy the entire width of the lobes at their widest parts. Examples of this type are to be found in *Lichas* and related genera, and for convenience of description it is here called the "*Metopolichas-Lichas*" type. The other type of pygidium is characterized by having the ribs produced in narrow spines which extend from the axial lobe and occupy only a part of the rib, usually the posterior half. Also the posterior pair of ribs are divided by a long, narrow posterior continuation of the axial lobe. This second type is characteristic of *Trochurus*, *Euarges*, and related genera, and is here called the "*Trochurus-Euarges*" type.

EVOLUTION

The evolution of the Lichadacea has been along two major lines: In one group of genera the glabella is characterized by the presence of complete third lateral furrows (the Trochuridae). In the other the third lateral furrows are never completely developed (the Lichadidae), although in some they are represented by pits or deviations on the longitudinal furrows, as in *Lichas* and related genera.

The ancestor of the Lichadacea is not known, although it is considered that the two families probably had a

common ancestor. The hexamerous lobation of the lichadian cephalon requires an ancestor with four pairs of lateral furrows on the glabella. Forms of this type existed in the Cambrian, such as *Redlichia*, *Zacanthoides*, *Albertella*, and *Paradoxides* but their direct relationship to lichads is questionable.

The two oldest genera, *Metopolichas* and *Platopolichas*, are derived directly from the hypothetical ancestor common to the superfamily. It appears likely that the rest of the Lichadidae are derived from the *Metopolichas* stem. *Metopolichas* by a posterior extension of the longitudinal furrows gave rise to the forms having tricomposite lobes and basal lobes, *Homolichas*, *Cypholichas*, *Hoplolichoides*, *Hoplolichas*, *Cyranolichas*, *Leiolichas*, and *Conolichas*. They represent a distinct evolutionary stage in possessing tricomposite lobes, and are confined to the Middle and Upper Ordovician. Another Middle and Upper Ordovician stage is represented by *Tetralichas*, *Kerakephalichas*, *Amphilichas*, and *Probolichas*. This group has quadricomposite lobes and is probably derived from the *Metopolichas* stem by the obsolescence of all the lateral glabellar furrows except the first and by the posterior extension of the longitudinal furrows. The Devonian forms possessing quadricomposite lobes probably descended, in similar manner, from *Lichas* through *Pseudotupolichas*.

In the Trochuridae there are four lines of more or less independent evolution. All can be derived from the common ancestor that is also the ancestor of the Lichadidae. A direct line from *Hemiarges*, through *Choneilobarges*, to *Euarges*, culminates in the Devonian *Mephiarges*, *Eifliarges*, and *Ceratarges*. In this line the most characteristic developments in the glabella are the obsolescence of the fourth lateral furrows, forming two pairs of bicomposite lobes, and the fusion of the posterior pair of bicomposite lobes with the fixed cheeks. *Trochurus* is in a second line, but is closely related to *Hemiarges* and to *Dicranopeltis*, which is in a third line. In the Upper Ordovician *Trochurus* gave rise to *Dicranogmus* by the disappearance of the anterior lateral furrows. By Silurian times *Richterarges* had evolved from *Dicranogmus* by the disappearance of the fourth lateral furrows. The *Trochurus* line culminated in the Devonian in the extremely spinose *Akantharges*. *Diplolichas* may be descended from a Silurian *Trochurus*. *Platylichas*, in a fourth line, is the oldest genus in which any of the lateral lobes are fused with the fixed cheeks.

The second lateral furrows are obsolete in all lichads. The disappearance of these furrows and the formation of the longitudinal furrows had occurred before the Lower Ordovician forms appeared. In the Lichadidae any indication of the third lateral furrows had almost disappeared by the Lower Ordovician, never to reappear in that family, and by Devonian time the fourth furrows had also disappeared.

Some striking evolutionary tendencies are displayed by the Lichadacea. The most obvious is the

spinose condition of nearly all the Devonian species of both families, as in *Akantharges*, *Mephiarges*, and *Gaspelichas*. Whether or not spinosity is an indication of racial senescence, it is interesting to observe that the greatest development of spinosity in the Lichadacea immediately precedes the disappearance of the group.

In the Lichadidae the major structural tendency is toward a glabella in which the third and fourth lateral furrows disappear, resulting in quadricomposite lobes. This goal was attained by *Tetralichas* as early as the Middle Ordovician, and all the Devonian Lichadidae have quadricomposite lobes.

The Trochuridae show an obstinate retention of the third lateral glabellar furrows, but the general tendency is for the fourth lateral furrows to disappear. The posterior bicomposite lobes thus formed tend to fuse with the fixed cheeks, a trend particularly noticeable in *Euarges* and related genera.

A striking example of parallelism in structure is seen in *Cyranolichas*, *Probolichas*, and *Makromuktis*. Although possessing important differences in glabellar lobation, each of these genera has the anterior glabellar lobe produced in a proboscis-like outgrowth. Another example of parallelism is seen in *Gaspelichas*, *Ceratolichas*, *Mephiarges*, and *Kerakephalichas*, all of which have one or more pairs of long recurved spines on the glabella.

PREVIOUS WORK

The most important studies of lichadian trilobites have been contributed by Gürich and Reed. Gürich (1901) divided the lichadian trilobites into two subfamilies, the Lichadinae and the Argetinae. Reed (1902) divided the lichads into two "groups," each of which was subdivided into several "sections." According to Reed (p. 81),

> the sections probably may be regarded as of subgeneric rank, though some are not so isolated as others, and all are not of equal value, and only the two groups can be considered generically separable.

Reed's "group" names, *Protolichas* and *Deuterolichas*, have no legal generic standing since neither has a type species. These are in reality subfamily divisions, although not so intended by the author. They have not been used, and must be discarded.

As pointed out by Warburg (1925), most modern workers have given the subgenera of Reed and Gürich generic rank. Reed's "sections" are as well-defined as genera in other families of trilobites, and it seems the most practical course to give them full generic standing. In both Reed's and Gürich's revisions of the genus *Lichas* the genus itself has been eliminated. Both authors listed the type species, *Lichas laciniatus*, under *Metopolichas*. In practice, both have given a generic name family standing.

PROPOSED CLASSIFICATION

The criteria for any classification must be based on the available parts, in most of the genera of the lichadian trilobites only the cephalon and pygidium. It has been pointed out that the furrows on the glabella have considerable morphological significance, and the differences which they

exhibit in number and arrangement are of considerable taxonomic value. The characteristics of the pygidium are also of value and are here used as second in importance to the glabellar lobation.

As has been pointed out in the discussion of the evolution of the lichads, the systematic units accepted as genera fall into two major evolutionary lines that arose from a common ancestor. Each of these lines is composed of closely related smaller aggregations of genera that also arose from the common ancestor. Any proper classification of lichadian trilobites should clearly catalogue this series of relationships.

The entire group of lichadian trilobites is here viewed as a superfamily, the Lichadacea. The two major lines are recognized as families, the Trochuridae and the Lichadidae. The smaller aggregations of genera are recognized as subfamilies.

As a general basis for the classification of trilobites is at present not available, it appears advisable to treat each family as a separate unit and to determine, if possible, the most important characters in that family for subdivision.

Phylum ARTHROPODA
Class CRUSTACEA
Subclass TRILOBITA
Order OPISTHOPARIA

Superfamily LICHADACEA Phleger, n. superfam.

Opisthoparian trilobites characterized by development in the glabella of longitudinal furrows extending from the first lateral furrows nearly or quite to the occipital furrow. Second lateral glabellar furrows obsolete or represented by pits only, and any of the other lateral furrows may be obsolete. Pygidium in most lichads with three pairs of pleural ribs, two or all of which may have discrete points. Entire surface pustulose.

Family LICHADIDAE Hawle and Corda (emend.)

Lichadacea in which the anterior lateral glabellar furrows are present, but third lateral furrows either obsolete or represented only by pits or bends on the longitudinal furrows. Pygidium of *Metopolichas-Lichas* type, with three pairs of ribs.

Subfamily LICHADINAE Gürich (emend.)

Lichadidae with bicomposite and basal glabellar lobes.

Genus PLATOPOLICHAS Gürich

Figures 1, 2

Platopolichas GÜRICH, *1901*, p. 522.—REED, *1923*, pp. 455, 458.

Genotype: *Lichas avus* Barrande (1872, pp. 50–52, pl. 5, fig. 23; pl. 6, figs. 22–26; pl. 10. figs. 12–19).

Lichadinae with third lateral lobes weakly defined mesally and anteriorly. Pygidium with three pairs of ribs ending in free points, without median furrows on the last pair; axial lobe with three pairs of furrows and narrowing posteriorly. *Platopolichas* differs in these respects from *Lichas* and *Metopolichas*.

Range: Lower Ordovician, Bohemia.

Genus LICHAS Dalman, s. s.

Figures 3, 4

Lichas DALMAN, *1826*, p. 278; *1828*, pp. 53, 71, 72, pl. 6, fig. 1.—WARBURG, *1925*, pp. 294, 295.

Genotype: *Entomostracites laciniatus* Wahlenberg (Nova Acta Soc. Reg. Sci. Upsula, vol. 8, p. 34, pl. 2, fig. 2, 1821, pygidium, not cranidium).

Lichadinae in which the longitudinal furrows end in notches at the third

lateral furrows. Pygidium with three pairs of ribs, anterior two pairs ending in free points; axial lobe with two furrows, flaring posteriorly.

Range: Middle and Upper Ordovician, Europe; Silurian, Europe, North America.

Discussion.—Much confusion has arisen from the usage of the term *Lichas*. Originally it was the only generic name in the Lichadacea, and species which are not congeneric are listed under *Lichas* by the older paleontologists. Gürich and Reed, in giving the so-called subgenera of *Lichas*, have retained the old name with generic rank and at the same time given each subgeneric name in parenthesis with each species. This usage has tended to eliminate *Lichas* as an independent genus. In order to rectify this confusion the genus *Lichas* is here restricted to those species which appear congeneric with the type species *Lichas laciniatus* (Wahlenberg).

Genus METOPOLICHAS Gürich

Figures 5, 6

Metopolichas GÜRICH, *1901*, p. 521, pl. 20, fig. 17.—REED, *1923*, p. 457.

Metopias EICHWALD, *1842*, p. 62.—SCHMIDT, *1885*, pp. 30–39.

Genotype: *Metopias hubneri* Eichwald (1842, pp. 62–63, pl. 3, figs. 21, 22).

Differs from *Lichas* in having the glabella strongly arched anteriorly, and a pygidium with a notch in the post-axial area.

Range: Lower and Middle Ordovician, Europe; Middle Ordovician, China.

Genus URALICHAS Delgado

Figures 9, 10

Uralichas DELGADO, *1892*, pp. 19–29, pls. 1–6.—REED, *1902*, p. 75, fig. 8.

Genotype: *Uralichas riberoi* Delgado, *op. cit.*

Differs from *Lichas* by large size and elongation, accentuated by long caudal spine.

Range: Middle Ordovician, Europe.

Subfamily ECHINOLICHADINAE Phleger, n. subfam.

Lichadidae with quadricomposite lobes and some degree of spinosity (except in *Pseudotupolichas* and *Arctinuroides*).

EXPLANATION OF FIGS. 1–20

FIGS. *1, 2—Platopolichas avus* (Barrande). *1*, Cephalon, natural size; *2*, pygidium. After Barrande (1872, pl. 10, figs. 12, 17). (p. 599)

3, 4—Lichas laciniatus (Wahlenberg). *3*, Cephalon; *4*, pygidium. After Angelin (1864 pl. 36, fig. 1). (p. 599)

5, 6—Metopolichas hubneri (Eichwald), lateral and dorsal views of the cranidium. After Eichwald (1842, pl. 3, figs. 21, 22). (p. 600)

7, 8—Pseudotupolichas ornatus (Angelin). *7*, Cranidium; *8*, pygidium. After Schmidt (1885, pl. 6, figs. 18, 20). (p. 602)

9, 10—Uralichas riberoi Delgado. *9*, A small pygidium; *10*, cranidium, natural size. After Delgado (1897, pl. 4, fig. 4, pl. 2, fig. 1). (p. 600)

11—Arctinuroides chicagoensis (Weller), cranidium. After Weller (1907, pl. 23, fig. 7). (p. 602)

12, 13—Ceratolichas dracon Hall. *12*, Dorsal view of cranidium; *13*, lateral view. After Hall (1888, pl. 18, figs. 7, 8). (p. 604)

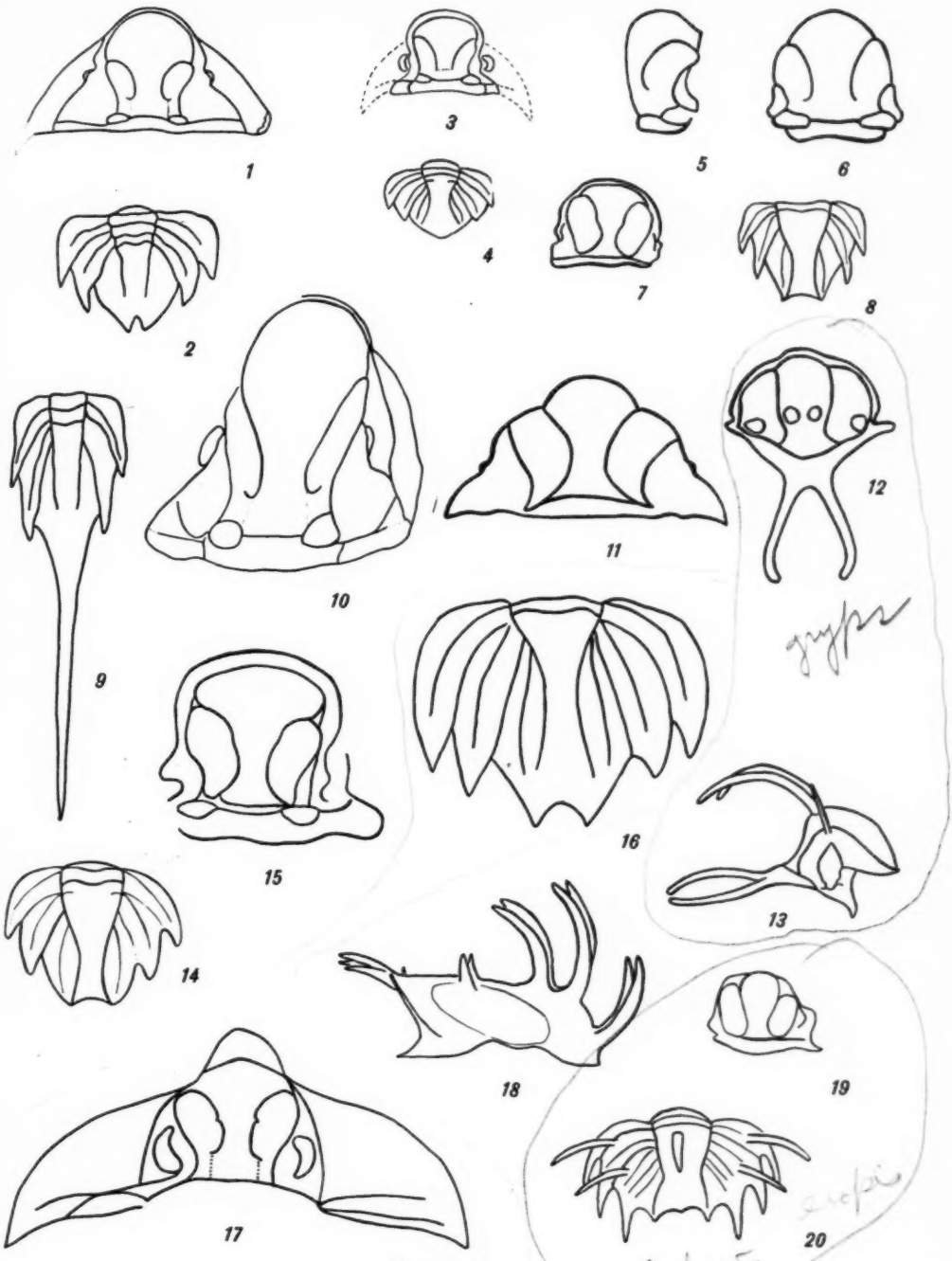
14—Arctinuroides chicagoensis (Weller), pygidium natural size. After Weller (1907, pl. 23, fig. 8). (p. 602)

15—Trimerolichas marginatus (Reed), cranidium. After Reed (1906, pl. 15, fig. 15). (p. 604)

16, 17—Arctinurus boltoni (Bigsby). *16*, Pygidium; *17*, cephalon. After type specimens in New York State Museum. (p. 602)

18—Gaspelichas forillonia Clarke, lateral view of cranidium. After Clarke (1908, pl. 2 figs. 1, 2). (p. 602)

19, 20—Echinolichas eriopis (Hall). *19*, Cranidium; *20*, restored pygidium. After Hall (1888, pl. 19A, figs. 2, 15). (p. 604)



FIGS. 1–20

Genus PSEUDOTUPOLICHAS Phleger, n. gen.

Figures 7, 8

Oncholichas REED (not Schmidt), *1902*, p. 76, fig. 10.

Genotype: *Lichas ornatus* Angelin (1854, p. 72, pl. 37, figs. 7, 7a).

Echinolichadinae with third lateral glabellar furrows represented by notches on the longitudinal furrows. Pygidium with a notch in the post-axial region.

Range: Silurian, Europe, North America.

Discussion.—This genus includes the species usually given as belonging to *Oncholichas* Schmidt. The name *Oncholichas* must be discarded, however, for the following reasons: *Arctinurus boltoni* (Bigsby) was given by Schmidt as the type of his genus *Oncholichas*. Inasmuch as Schmidt's description was based on Baltic specimens of *Lichas ornatus*, Reed referred to the latter species as the type. *Arctinurus boltoni* is, however, the type of *Arctinurus*, and therefore *Oncholichas* is a synonym of *Arctinurus*.

Genus ARCTINUROIDES Phleger, n. gen.

Figures 11, 14

Genotype: *Arctinurus chicagoensis* Weller (1907, p. 248, pl. 23, figs. 7, 8, pl. 22, fig. 14).

Echinolichadinae with inflated glabella and with quadricomposite lobes diverging anteriorly and rapidly narrowing at the occipital furrow.

Range: Middle Silurian, North America.

Genus GASPELICHAS Clarke

Figure 18

Gaspelichas CLARKE, *1907*, New York State Mus., Bull. 107, p. 167, fig. 1; *1908*, New York State Mus., Mem. 9, pt. 1, p. 137, pls. 1–3.

Genotype: *Gaspelichas forillonia* Clarke, *op. cit.*

Echinolichadinae with cephalon elongate, inflated, spinose; occipital segment produced in spines.

Range: Lower Devonian, North America.

EXPLANATION OF FIGS. 21–47

FIGS. *21*, *22*—*Cypholichas branconis* (Pompecki), dorsal and lateral views of glabella. After Pompecki (1890, pl. 2, figs. 26, 26*a*). (p. 604)

23—*Hoplolichoides conicotuberculatus* (Nieszkowski), cranidium. After Schmidt (1885, pl. 3, fig. 14). (p. 605)

24, *25*—*Homolichas depressus* (Angelin). *24*, Pygidium; *25*, cranidium. After Angelin (1854, pl. 36, figs. 4, 4*a*). (p. 604)

26, *27*—*Radiolichas araneus* (Holzapfel). *26*, Cranidium; *27*, pygidium. After Holzapfel (1895, pl. 13, figs. 1, 2). (p. 604)

28—*Cyranolichas proboscidus* (Dames), cranidium. After Dames (1877, pl. 12, fig. 4). (p. 605)

29, *30*—*Terataspis grandis* Hall, pygidium and cranidium, natural size. After Hall (1888, pl. 19, figs. 1, 3). (p. 604)

31–33—*Hoplolichas tricuspidatus* (Beyrich). *31*, Pygidium; *32*, *33*, dorsal and lateral views of cranidium. After Dames (1877), pl. 13, fig. 1, 1*a*). (p. 605)

34–36—*Leiolichas illaenoides* (Nieszkowski). *34*, *35*, Dorsal and lateral views of cranidium; *36*, pygidium. After Schmidt (1885, pl. 3, figs. 27*a*, *b*, 30). (p. 605)

37–39—*Conolichas schmidti* (Dames). *37*, *38*, Anterior and lateral views of cranidium; *39*, pygidium. After Schmidt (1885, pl. 4, figs. 36*b*, *c*, 38). (p. 605)

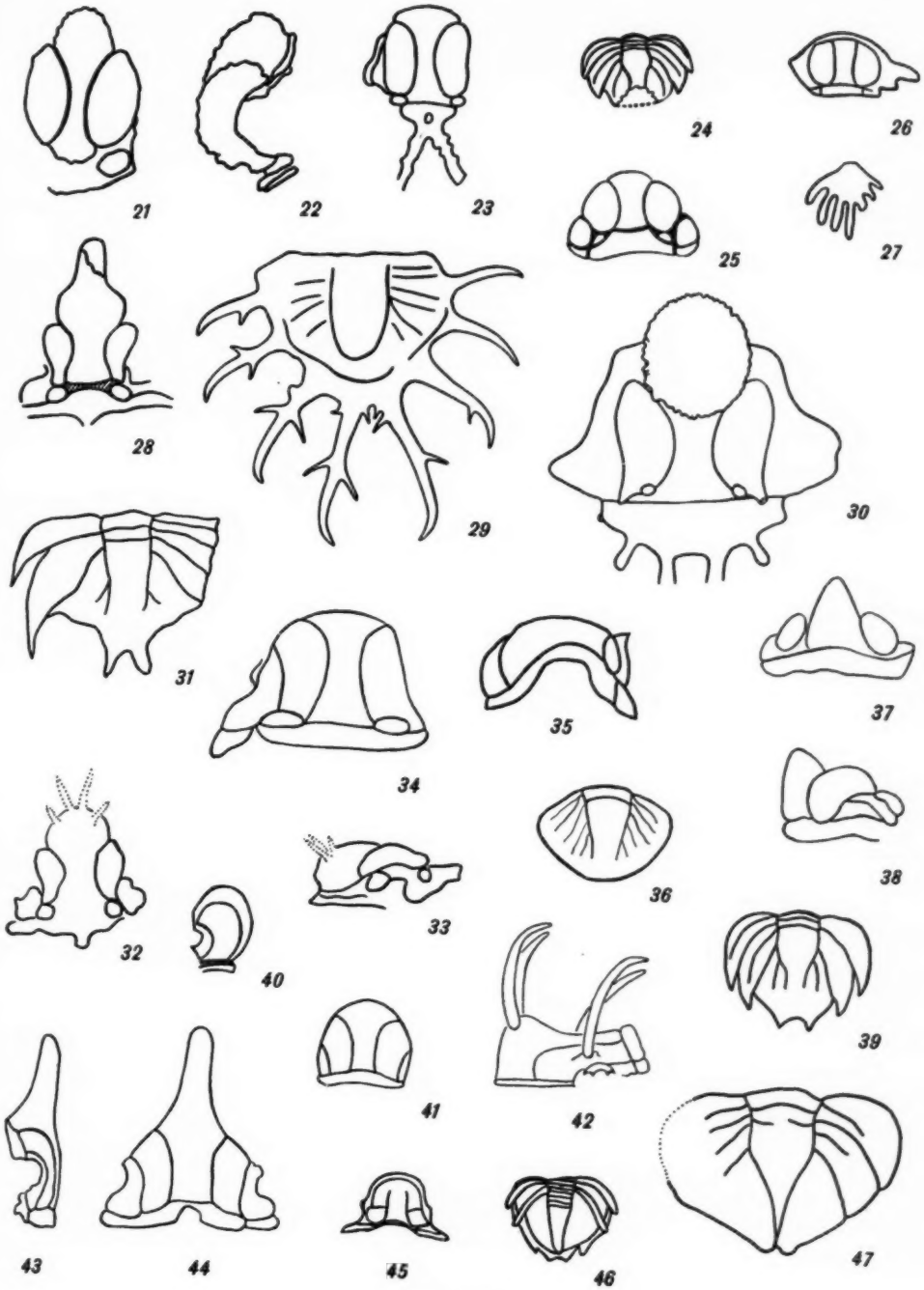
40, *41*—*Tetralichas laevis* (Eichwald), lateral and dorsal views of glabella. After Eichwald (1852, pl. 54, figs. 16*a*, *b*). (p. 605)

42—*Kerakephalichas rhinoceras* (Slocom), restoration of cranidium, lateral view. After Slocom (1913, pl. 15, fig. 6). (p. 606)

43, *44*—*Probolichas robbinsi* (Ulrich), lateral and dorsal views of cranidium. After Clarke (1894, text-figs. 68, 69). (p. 606)

45, *46*—*Richterarges ptyonurus* (Hall). *45*, Cranidium; *46*, pygidium. After Hall (1888, pl. 19B, figs. 19, 21). (p. 608)

47—*Tetralichas trentonensis* (Conrad), pygidium. After Foerste (1920, pl. 3, fig. 4*b*). (p. 605)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FIGS. 21–47

Genus ECHINOLICHAS Gürich

Figures 19, 20

Echinolichas GÜRICH, *1901*, p. 530.—REED, *1902*, p. 79.

Genotype: *Lichas eriopis* Hall (1863, p. 226); *Conolichas eriopis* Hall (1888, p. 78, pl. 19a, figs. 2–13, 15, 16).

Echinolichadinae with anterior glabellar lobe inflated and covered with spiny tubercules. Pygidium with three pairs of ribs ending in free points; axial lobe with two furrows and flaring posteriorly.

Range: Lower and Middle Devonian, North America.

Genus TERATASPIS Hall

Figures 29, 30

Terataspis HALL, *1863*, p. 223.—HALL, *1888*, p. 73, pls. 17–19.

Genotype: *Lichas grandis* Hall (1862, p. 82).

Echinolichadinae with elongate glabella; anterior lobe bulbous and covered with spiny tubercules, completely circumscribed, with a depressed pre-occipital area. Pygidium with four pairs of barbed spines.

Range: Middle Devonian, North America.

Genus CERATOLICHAS Hall

Figures 12, 13

Ceratolichas HALL, *1888*, p. 11, text-fig.—REED, *1902*, p. 81.

Genotype: *Ceratolichas gryps* Hall and Clarke (1888, p. 84, pl. 19b, figs. 7–13).

Echinolichadinae with strongly arched cephalon having two pairs of recurved spines; one pair of occipital spines.

Range: Middle Devonian, North America.

Genus RADIOLICHAS Reed

Figures 26, 27

Radiolichas REED, *1923*, p. 459.

Genotype: *Lichas araneus* Holzapfel (1895, p. 32, pl. 3, fig. 11; pl. 13, figs. 1–3, 16).

Differs from *Pseudotupolichas* in having the ribs of the pygidium produced in long spines and in having a smooth axial lobe.

Range: Middle Devonian, Germany.

Subfamily HOMOLICHADINAE Phleger, n. subfam.

Lichadidae with tricomposite lobes and basal lobes.

Genus HOMOLICHAS Schmidt

Figures 24, 25

Homolichas SCHMIDT, *1885*, p. 94.—REED, *1902*, pp. 77, 78.—GÜRICH, *1901*, pp. 524, 525.

Platylichas GÜRICH (part) and of authors.

Genotype: *Lichas depressus* Angelin (1854, p. 70, pl. 36, figs. 4, 4*a*).

Homolichadinae with very convex glabella. Pygidium with three pairs of ribs, anterior two pairs ending in free points; axial lobe with two furrows, flaring posteriorly.

Range: Middle and Upper Ordovician, North America, Europe; Silurian, Europe.

Genus TRIMEROLICHAS Phleger, n. gen.

Figure 15

Genotype: *Lichas marginatus* Lindström (1885, p. 58, pl. 14, figs. 8, 9).

Differs from *Homolichas* in having a fairly wide brim on the anterior part of the cephalon.

Range: Middle Silurian, North America; Upper Silurian, Europe.

Genus CYPHOLICHAS Phleger, n. gen.

Figures 21, 22

Genotype: *Homolichas branconis* Pompecki (1890, p. 48, pl. 2, figs. 26, 26*a*).

Differs from *Homolichas* in having very deep glabellar furrows. Surface coarsely tuberculate. Glabella differs from *Conolichas* in being strongly arched throughout its entire length.

Range: Boulders, Germany.

Genus HOPLOLICHOIDES Phleger, n. gen.

Figure 23

Genotype: *Lichas conicotuberculatus* Nieszkowski (1857, p. 364, pl. 1, figs. 7–10); *Hoplolichas conicotuberculatus* Schmidt (1885, p. 82, pl. 3, figs. 13–25).

Differs from *Hoplolichas* in having no spines on the anterior lobe of the glabella.

Range: Middle Ordovician, Europe.

Genus HOPLOLICHAS Dames

Figures 31–33

Hoplolichas DAMES, *1877*, p. 794.—REED, *1902*, p. 77.

Genotype: *Lichas tricuspidatus* Beyrich (1846, p. 7, pl. 1, figs. 7*a*, 7*b*); *Hoplolichas tricuspidatus* Schmidt (1885, p. 69, pl. 2, figs. 12–16).

Glabella with anterior lobe produced in spines; occipital segment produced in spines. Pygidium with three pairs of ribs, the anterior two pairs ending in free points; axial lobe with two furrows, flaring posteriorly.

Range: Middle Ordovician, Europe.

Genus CYRANOLICHAS Phleger, n. gen.

Figures 28, 59

Genotype: *Hoplolichas proboscideus* Dames (1877, p. 800); Wigand (1888, p. 645, pl. 8, figs. 2, 3).

Differs from *Hoplolichas* in having the anterior glabellar lobe produced in a blunt proboscis-like projection.

Range: Boulders, Germany.

Genus LEIOLICHAS Schmidt

Figures 34–36

Leiolichas SCHMIDT, *1885*, pp. 29, 30, 46, pl. 3, figs. 27–31.

Genotype: *Platymetopus illaenoides* Neiszkowski (1857, p. 662, pl. 3, figs 3–5).

Differs from *Homolichas* in having a fairly smooth pygidium, with one furrow on the axial lobe; pleural furrows faint, not reaching the smooth border.

Range: Middle Ordovician, Europe.

Genus CONOLICHAS Dames

Figures 37–39

Conolichas DAMES, *1877*, p. 806, pl. 13, fig. 5.—SCHMIDT, *1885*, pp. 30, 40, 87.—REED, *1902*, pp. 78, 79, figs. 15*a*, *b*.

Genotype: *Lichas aequiloba* Steinhardt, 1874, p. 30, pl. 3, fig. 6.

Homolichadinae with glabella distinguished by the conical dorsal protuberance of the anterior lobe, and preoccipital median depression. Pygidium with three pairs of discrete ribs; axial lobe with two rings and flaring posteriorly.

Range: Ordovician, North America, Europe.

Subfamily TETRALICHADINAE Phleger, n. subfam.

Lichadidae with quadricomposite lobes, except in *Amphilichas*, which is descended from a form with quadricomposite lobes.

Genus TETRALICHAS Phleger, n. gen.

Figures 40, 41, 47

Platymetopus ANGELIN (part), *1854*, p. 68.
Paralichas REED (part), *1902*, p. 80.
Amphilichas RAYMOND (part), *1905*, Am. Jour. Sci., ser. 4, vol. 19, p. 378 (and other authors).
Acrolichas FOERSTE (part), *1920*, pp. 26–50.

Genotype: *Lichas laevis* Eichwald (1852–69, pp. 1387, 1388, pl. 54, figs. 16*a*, *b*); Schmidt (1885, pp. 49–53, pl. 6, figs. 5–10).

Tetralichadinae with broadly inflated glabella. Axial lobe of pygidium with two furrows, narrowing posteriorly. Differs from *Amphilichas* in having the longitudinal furrows well-incised and in having distinct quadricomposite lobes.

Range: Middle and Upper Ordovician, Europe, North America; Ordovician, Greenland, India.

Discussion.—Foerste (1921) erected the genus *Acrolichas* to include the American forms and one Irish form which have typical "*Amphilichas*" (*Tetralichas*) cranidia but which have pygidia with the axial lobe produced posteriorly in a point, being unlike the pygidia referred

to *A. holmi* and *A. lineatus* by Schmidt (1885, p. 52, pl. 6, fig. 10; 1907. p. 26, pl. 2, fig. 14, text-figs. 3, 12). Warburg (1925) reports several "*Amphilichas*" (*Tetralichas*) cranidia from the *Leptaena* limestone

> and also several pygidia of the "*Acrolichas*" type, but not a single pygidium resembling those referred (by Schmidt) to *A. holmi* and *A. lineatus*.

Schmidt associated the pygidia and cranidia, found at the same locality, on the basis of the similarity of ornamentation. According to Warburg,

> this does not seem to be proof enough, since several species of the Lichadidae belonging to different groups and genera show great resemblance in ornamentation of the test.

Warburg is of the opinion that the pygidia found by Schmidt probably belong to *Homolichas angustus*, which is found at the same locality. It is true that the type of pygidium referred to *Tetralichas* by Schmidt differs in no essential respect from the pygidia of *Lichas* and *Homolichas*. It appears that the characters of the pygidium of *Acrolichas*, noted by Foerste, are of doubtful value. It is true, however, that the type species of *Acrolichas*, *A. cucullus* (Meek and Worthen), is distinct from other Tetralichadinae in having a conical dorsal protuberance on the median glabellar lobe, and in this respect it resembles *Conolichas*. It seems advisable to restrict *Acrolichas* to its type species.

Angelin described the genus *Platymetopus*, type *P. lineatus*, as a genus of equal standing with *Lichas*. A second species, *P. planifrons*, was questionably assigned to the genus. Reed (1902) found *Platymetopus* preoccupied and proposed *Paralichas* to replace it, giving *P. planifrons* as the type. Later, Gürich listed *P. holmi* as the type. In 1905 Raymond found *Paralichas* preoccupied and proposed the name *Amphilichas* with *A. laevis* as the type species. The confusion of the type of this genus has led to the inclusion under it of a variety of forms which are generically separable. It appears that the type of glabella which has been regarded as typical of *Amphilichas* is greatly different from Angelin's type, *A. lineatus;* the species which show the typical quadricomposite lobation in the glabella must be placed in the new genus *Tetralichas*.

Genus KERAKEPHALICHAS Phleger, n. gen.

Figure 42

Genotype: *Amphilichas rhinoceras* Slocom (Field Mus. Nat. Hist., Publ., Geol. Ser., vol. 4, no. 3, 1913, p. 58, pl. 15, figs. 5, 6).

The glabella differs from *Tetralichas* in supporting one or more pairs of hornlike processes.

Range: Middle Ordovician, North America.

Genus AMPHILICHAS Raymond, s.s.

Figures 48, 49

Amphilichas RAYMOND (part), *1905*, Am. Jour. Sci., ser. 4, vol. 19, p. 378.—REED (part), *1902*, p. 80.—WARBURG (part), *1925*, pp. 308, 309.

Genotype: *Platymetopus lineatus* Angelin (1854, p. 75, pl. 38, figs. 12, 12*a*).

Tetralichadinae with bicomposite glabellar lobes; longitudinal furrows incomplete and faintly incised; third lateral furrows only indicated mesially.

Range: Upper Ordovician, Sweden.

Genus PROBOLICHAS Phleger, n. gen.

Figures 43, 44

Genotype: *Hoplolichas robbinsi* Ulrich (1892, Am. Geol., vol. 10, p. 271, figs. 1*a–b*).

Differs from *Tetralichas* in having the anterior glabellar lobe produced in a blunt proboscis-like extension.

Range: Upper Ordovician, North America.

Genus ACROLICHAS Foerste

Acrolichas FOERSTE (part), *1919*, Ohio Jour. Sci., vol. 19, p. 402.

Genotype: *Lichas cucullus* Meek and Worthen (1868, Geol. Survey Illinois, vol. 3, p. 299, pl. 1, figs. 6*a–c*).

The glabella differs from *Tetralichas* in having the median lobe produced dorsally in a cone-like projection.

Range: Middle Ordovician, North America.

Family TROCHURIDAE Phleger, n. fam.

Lichadacea having complete lateral glabellar furrows. The longitudinal furrows extend to the occipital furrow in all except *Akantharges*.

Subfamily TROCHURINAE Phleger, n. subfam.

Trochuridae in which the central form has a glabella with longitudinal, fourth lateral, and axial furrows complete. In later forms the anterior lateral furrows are obsolete, and the fourth lateral furrows may disappear. *Trochurus-Euarges* type of pygidium.

Genus TROCHURUS Beyrich

Figures 50, 53

Trochurus BEYRICH, *1845*, p. 31.—FOERSTE, *1917*, Ohio Jour. Sci., vol. 17, no. 7, p. 254.
Corydocephalus HAWLE and CORDA, *1847*, p. 139, pl. 7, fig. 74.—REED, *1902*, p. 71.—WELLER, *1907*, p. 234.
Plusiarges GÜRICH, *1901*, p. 527.

Genotype: *Trochurus speciosus* Beyrich (1845, p. 31, pl. 1, fig. 14).

Trochurinae with convex glabella; axial, longitudinal, and fourth lateral furrows complete; lateral lobes strongly convex, set off from median lobe by deep furrows; third lateral furrows continuous across median lobe. Pygidium with three pairs of discrete ribs; axial lobe with two furrows, narrowing posteriorly.

Range: Upper Ordovician, Silurian, Devonian, Europe; Silurian, North America.

Discussion.—Beyrich (1845) described the cephalon of a *Staurocephalus* and the pygidium of a lichad as *Trochurus speciosus* and the type of the genus *Trochurus*, but the pygidium only was figured. In 1846 he realized his mistake and figured the proper lichad cephalon which belonged with the *T. speciosus* pygidium, but he considered *Trochurus* the equivalent of *Arges* and so figured the species under the name *Arges speciosus*. The cranidium which he had described the previous year under the name *T. speciosus*, but had not figured, he then figured and correctly referred to *Staurocephalus murchisoni* Barrande.

Hawle and Corda (1847) considered that *Trochurus speciosus* was based on the cephalon which Beyrich had described but not figured, and they considered the species a synonym of *Staurocephalus murchisoni*. In the same paper *Corydocephalus* was named and *Trochurus* and *Arges* were given as synonyms. *Corydocephalus flabellatus* was described as a new species, the type of the genus *Corydocephalus*, and *Lichas palmatus* Barrande was listed as a synonym. (*L. palmatus* Barrande belongs to *Trochurus*.)

The pygidium of Barrande's *Lichas palmatus* is identical with the pygidium of *Trochurus speciosus*, as Barrande himself pointed out (1852), and *Lichas palmatus*, being the equivalent of *Corydocephalus flabellatus*, is then the type of *Corydocephalus*.

Hawle and Corda were not justified in picking the cephalon as the type of *Trochurus speciosus* because Beyrich had definitely fixed upon the pygidium as the type in his publication of the previous year. *Trochurus* thus antedates *Corydocephalus* by two years and has a good legal standing. I agree with Foerste that Beyrich's earlier name should be used.

There has been some confusion concerning the English species *Lichas anglicus* Beyrich. Beyrich described and figured a typical *Lichas* (s. s.) cranidium, but no pygidium. Of the specimens figured by Reed and Fletcher and referred to *Corydocephalus* (*Trochurus*)

the pygidia belong to that genus, but the cranidia do not nor do they appear to agree with Beyrich's description and figure.

Genus DICRANOGMUS Hawle and Corda

Figures 51, 52

Dicranogmus HAWLE and CORDA, *1847*, p. 145, pl. 7, fig. 77.
Liparges GÜRICH, *1901*, p. 528.

Genotype: *Lichas simplex* Barrande (1846, p. 55; 1852, pp. 608, 609, pl. 28, figs. 14, 15).

Trochurinae with strongly arched cranidium; with basal glabellar lobes; anterior lateral furrows obsolete; third lateral lobes confluent with fixed cheeks.

Range: Upper Ordovician, Silurian, Europe.

Genus RICHTERARGES Phleger, n. gen.

Figures 45, 46

Genotype: *Dicranogmus ptyonurus* Hall (1888, p. 86, pl. 19*b*, figs. 19–21).

Differs from *Dicranogmus* in having posterior bicomposite lobes fused with fixed cheeks. Pygidium with anterior two pairs of ribs produced in spines, posterior pair not defined; axial lobe with three rings, narrowing posteriorly.

Range: Silurian, Europe, North America.

Genus DIPLOLICHAS Phleger, n. gen

Figures 54, 55

Genotype: *Lichas maueri* Novak (1890, p. 122, pl. 21, figs. 9, 9*a*).

EXPLANATION OF FIGS. 48–81

FIGS. *48*, *49*—*Amphilichas lineatus* (Angelin), dorsal and lateral views of cranidium. After Angelin (1854, pl. 38, figs. 12, 13). Modified after plastotype in Mus. Comp. Zool. (p. 606)

50, *53*—*Trochurus speciosus* Beyrich. *50*, Cranidium; *53*, pygidium. After Beyrich (1846, pl. 1, figs. 1*a*, 1*c*. (p. 607)

51, *52*—*Dicranogmus simplex* (Barrande), lateral and dorsal views of cranidium. After Barrande (1852, pl. 28, figs. 14, 15). (p. 608)

54, *55*—*Diplolichas maueri* (Novak), dorsal and postero-lateral views of cranidium. After Novak (1890, pl. 3, figs. 9, 9*a*). (p. 608)

56, *57*—*Akantharges gourdonni* (Barrois). *56*, Cephalon; *57*, pygidium. After Barrois (1885, pl. 2, fig. 1*h*). (p. 610)

58, *60*—*Hemiarges wesenbergensis* (Schmidt). *58*, Pygidium; *60*, cranidium. After Schmidt (1885, pl. 6, figs. 1*a*, 2*a*). (p. 610)

59—*Cyranolichas proboscideus* (Dames), pygidium. After Dames (1877, pl. 13, fig. 4). (p. 605)

61, *62*—*Euarges haueri* (Barrande), lateral and dorsal views of cephalon. After Barrande (1852, pl. 28, figs. 41, 44). (p. 610)

63–65—*Eifliarges caudimirus* R. and E. Richter. *63*, Pygidium; *64*, *65*, lateral and posterior views of cephalon. After R. and E. Richter (1917, figs. 1*a*, 1*d*, 1*e*). (p. 612)

66, *67*—*Dicranopeltoides decipiens* (Weller). *66*, Pygidium; *67*, cephalon. After Weller (1907, pl. 22, figs. 10, 11). (p. 612)

68, *69*—*Choneilobarges macculochi* (Reed). *68*, A composite sketch of Reed's figures of the glabella; *69*, pygidium. After Reed (1913, pl. 4, figs. 9, 10). (p. 610)

70—*Euarges haueri* (Barrande), pygidium. After Barrande (1852, pl. 28, fig. 38). (p. 610)

71, *72*—*Dicranopeltis scabra* (Beyrich). *71*, Cephalon. *72*, pygidium. After Barrande (1852, pl. 28, figs. 22, 24). (p. 612)

73, *74*—*Platylichas margaritifer* (Nieszkowski). *73*, Cranidium, after Nieszkowski (1857, pl. 1, fig. 15); *74*, pygidium, after Schmidt (1885, pl. 5, fig. 23). (p. 614)

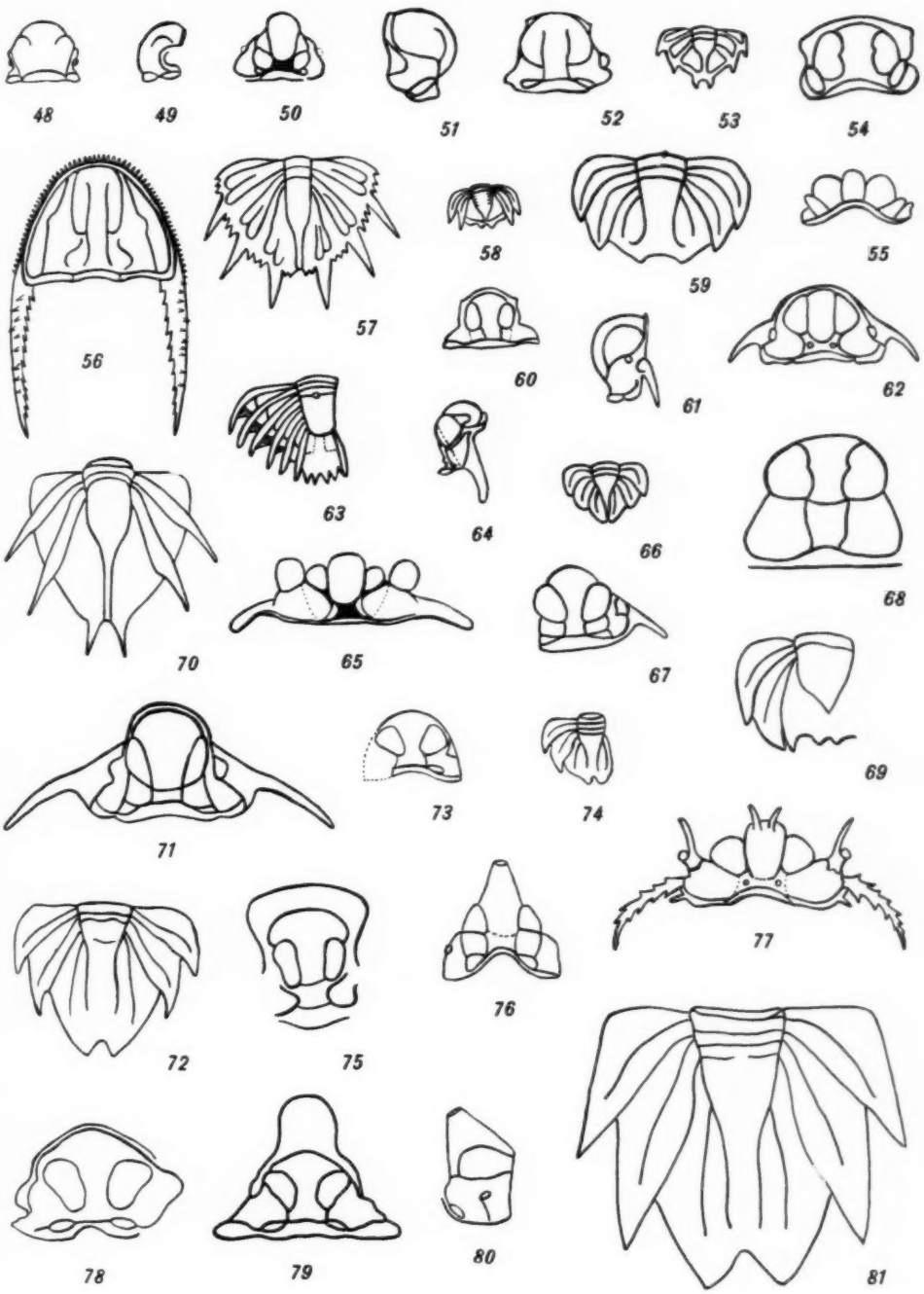
75—*Craspedarges wilcanniae* Gürich, cranidium. After Gürich (1901, pl. 18, fig. 1). (p. 612)

76, *80*—*Makromuktis nasuta* (Weller), dorsal and lateral views of cranidium. (p. 612)

77—*Mephiarges mephisto* R. and E. Richter, postero-dorsal view of cephalon. After R. and E. Richter (1930, text fig. 7*c*). (p. 612)

78—*Autoloxolichas st.-mathiae* (Schmidt), cranidium. After Schmidt (1885, pl. 5, fig. 11). (p. 614)

79, *81*—*Lingucephalichas planifrons* (Warburg). *79*, Cranidium; *81*, large pygidium. After Warburg (1925, pl. 6, figs. 11, 16). (p. 614)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FIGS. 48–81

Trochurinae with completely defined doubly bicomposite lobes; posterior lobes outside the anterior lobes (laterally); second lateral furrow indicated on longitudinal furrow by an identation.

Range: Lower Devonian, Germany.

Genus AKANTHARGES Phleger, n. gen.

Figures 56, 57

Genotype: *Lichas gourdonni* Barrois (1885, Soc. Géol. Nord, Ann., vol. 13, pp. 126–128, pl. 2, fig. 1).

Cephalon elongate, with rim and long genal spines very spinose; first and fourth glabellar furrows incomplete; longitudinal furrows incomplete posteriorly and anteriorly. Pygidium very spinose.

Range: Devonian, France.

Subfamily EUARGINAE Gürich (emend.)

Trochuridae with doubly bicomposite glabellar lobes. Posterior bicomposite lobes completely confluent with fixed cheeks, except in *Hemiarges*. *Trochurus-Euarges* type of pygidium.

Genus EUARGES Gürich

Figures 61, 62, 70

Euarges GÜRICH, *1901*, p. 527.—REED, *1923*, pp. 456, 457.

Acanthopyge HAWLE and CORDA, *1847*, p. 144.

Genotype: *Lichas haueri* Barrande (1846, p. 73; 1852, pp. 604–606, pl. 28, figs. 36–44).

Euarginae having a pygidium with three pairs of ribs ending in spines; axial lobe with two furrows, narrowing posteriorly into a strap-like extension.

Range: Silurian, Europe, Australia; Devonian, Europe, North America.

Discussion.—The species *Euarges beryllifer* (Richter) is based on an isolated pygidium and was questionably referred to *Trochurus* by its describer. Inasmuch as no other species of *Trochurus* occurs in the Devonian, it appears likely that it can be placed in *Eurages*.

Genus HEMIARGES Gürich

Figures 58, 60

Hemiarges GÜRICH, *1901*, p. 526.—FOERSTE, *1920*, pp. 28, 29.

Genotype: *Lichas wesenbergensis* Schmidt (1888, p. 44, pl. 6, figs. 1–4).

Euarginae with fourth lateral glabellar furrows indicated by notches on longitudinal furrows; axial furrow very weakly incised posteriorly. Pygidium with no median furrow on posterior pair of ribs; two short marginal spines on each of posterior pair of ribs.

Range: Ordovician, Europe, Greenland, North America.

Genus CHONEILOBARGES Phleger, n. gen.

Figures 68, 69

Genotype: *Corydocephalus macculochi* Reed (1913, p. 28, pl. 4, figs. 9, 10).

Differs from *Hemiarges* in the extension of the third lateral furrows across the median glabellar lobe, and in complete confluence of the posterior bicomposite lobes with the fixed cheeks.

Range: Upper Ordovician, Europe.

Discussion.—This genus differs from *Hemiarges* in having the third lateral glabellar furrows continuous across the median lobe. It resembles *Trochurus* but lacks the depressed pre-occipital area; the fusion of the third lateral lobes and the basal lobes is also more advanced than in *Trochurus*. In the nearly complete fusion of the posterior bicomposite lobes with the fixed cheeks this genus resembles *Eurages*, but in other respects, and particularly in the characters of the pygidium, it is most like *Hemiarges*.

Genus CERATARGES Gürich

Ceratarges GÜRICH, *1901*, p. 531.
Arges GOLDFUSS, *1839*, p. 355.

Genotype: *Arges armatus* Goldfuss (1839, p. 355, pl. 33, figs. 1*a–c*).

Euarginae with inflated and spinose cephalon; stalked eyes. Pygidium very spinose.

Range: Middle Devonian, Germany.

Discussion.—Richter's figures of this

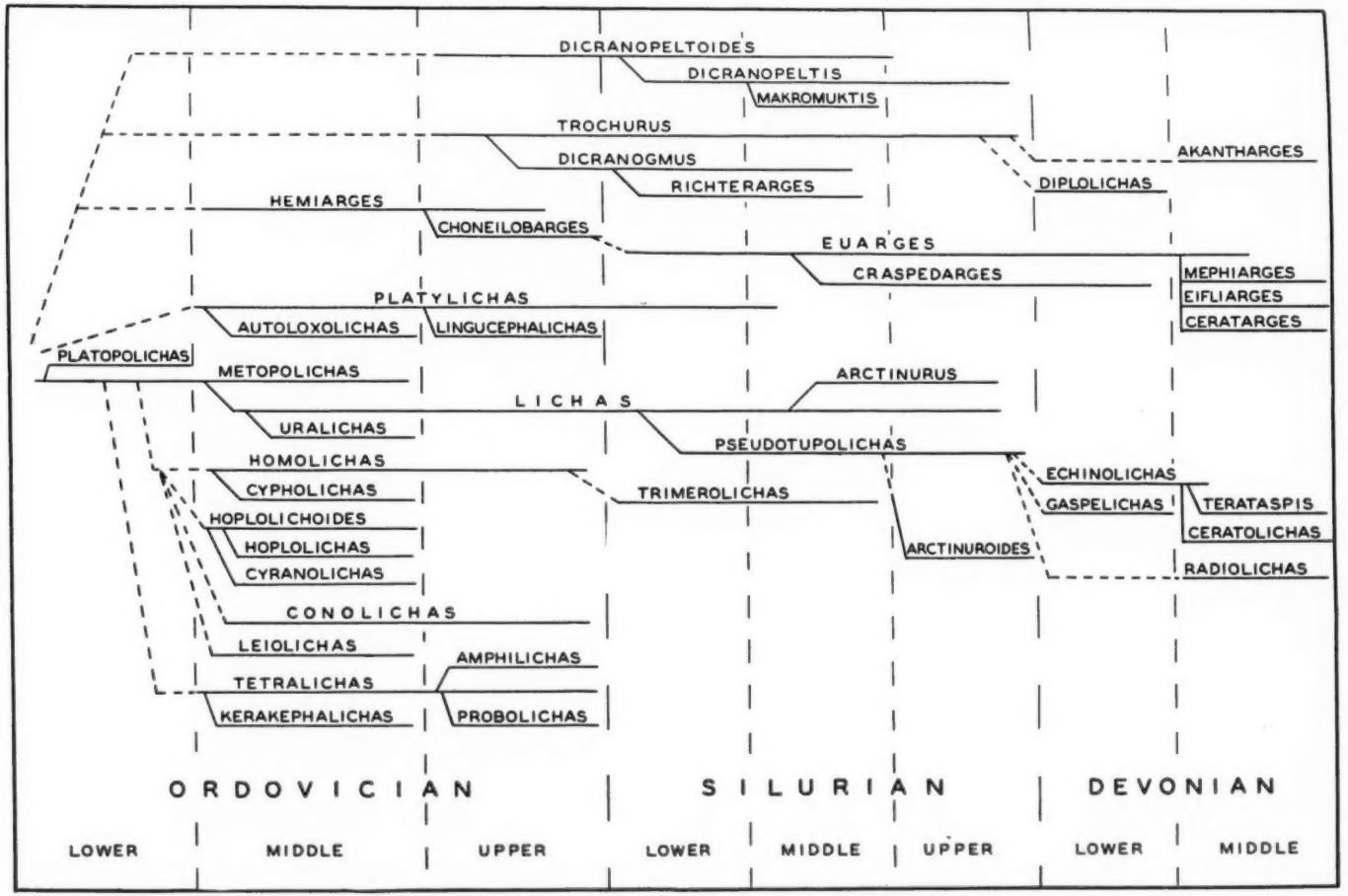

FIG. 82—Chart showing the evolution of lichadian trilobites.

curious species are usually considered the most accurate.

Genus CRASPEDARGES Gürich

Figure 75

Craspedarges GÜRICH, *1901*, pp. 532–534.—REED, *1923*, p. 457.

Genotype: *Craspedarges wilcanniae* Gürich (1901, pp. 532–534, pl. 20, fig. 20).

Euarginae with cephalon having a wide anterior border; third lateral glabellar furrows extending across median lobe, with a large pre-occipital depressed area. Pygidium with three pairs of ribs with free points, and apparently no median furrow on last pair; axial lobe with several furrows, narrowing posteriorly to a point.

Range: Silurian, Europe; Devonian, Australia.

Genus EIFLIARGES R. and E. Richter

Figures 63–65

Eifliarges R. and E. RICHTER, *1917*, pp. 68–71.—REED, *1923*, p. 457.

Genotype: *Eifliarges caudimirus* R. and E. Richter (1917, pp. 55–68, pl. 5, figs. 1*a–f*).

Euarginae having inflated cephalon, with large, elevated, bulbous eyes, glabella with deep furrows and median pre-occipital depressed area; third lateral furrows extending across median lobe. Pygidium with short axial lobe having two or three furrows; six pairs of ribs ending in spines, with two additional pairs of points on the posterior margin.

Range: Devonian, Germany.

Genus MEPHIARGES R. and E. Richter

Figure 77

Mephiarges R. and E. RICHTER, *1930*, pp. 39–41, figs. 7*a–c*.

Genotype: *Euarges mephisto* R. and E. Richter (1917, pp. 146–149, fig. 2).

Differs from *Euarges* in having barbed genal spines, spines on the anterior glabellar lobe, and eyes on spiny stalks.

Range: Devonian, Germany.

Subfamily DICRANOPELTINAE Phleger, n. subfam.

Trochuridae with third and fourth lateral glabellar furrows complete in all cases. Pygidium of the *Metopolichas-Lichas* type.

Genus DICRANOPELTIS Hawle and Corda

Figures 71, 72

Dicranopeltis HAWLE and CORDA, *1847*, p. 141, pl. 7, fig. 75.
Trachylichas GÜRICH, *1901*, p. 525.

Genotype: *Lichas scabra* Beyrich (1845, p. 28, fig. 16).

Dicranopeltinae with third lateral glabellar furrows extending across median lobe. Pygidium with two anterior pairs of ribs having free points; axial lobe with two furrows, narrowing posteriorly.

Range: Silurian, Europe, North America.

Genus DICRANOPELTOIDES Phleger, n. gen.

Figures 66, 67

Genotype: *Lichas decipiens* Winchell and Marcy (1865, Boston Soc. Nat. Hist. Mem., vol. 1, p. 104); Weller (1907, p. 237, pl. 22, figs. 10–11).

Dicranopeltinae with third lateral glabellar furrows not continuous across the median lobe. Pygidium with three pairs of discrete ribs; axial lobe narrowing posteriorly to a point. In other respects like *Dicranopeltis*.

Range: Upper Ordovician, Europe; Silurian, Europe, North America.

Genus MAKROMUKTIS Phleger, n. gen.

Figures 76, 80

Genotype: *Dicranopeltis nasuta* Weller (1907, p. 240, pl. 22, figs. 5–7).

Differs from *Dicranopeltis* in having a strongly inflated glabella, with the an-

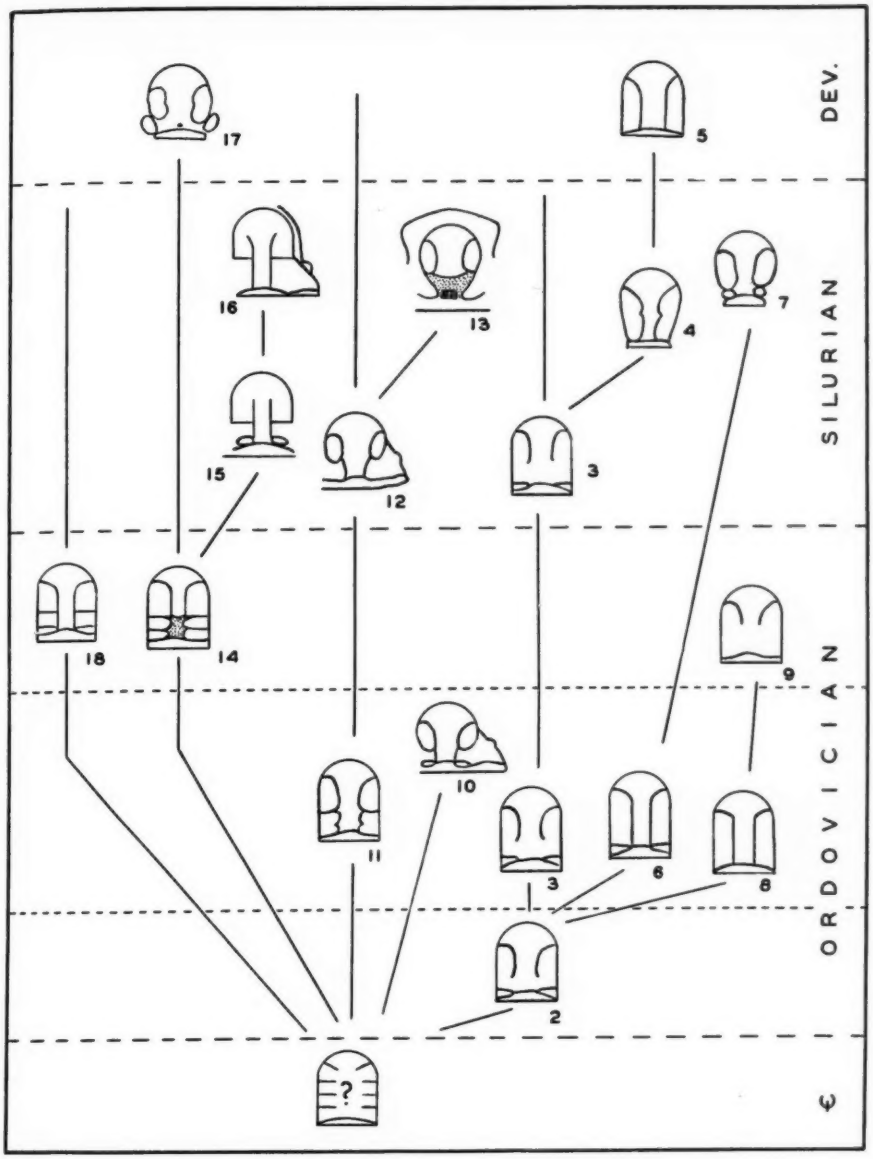

FIG. 83—Evolution of the lichadian glabella. The diagrams illustrate the key stages in the development of the lichadian glabella.

1. The hypothetical ancestor.
2. *Metopolichas-Platopolichas* stage.
3. *Lichas* stage.
4. *Pseudotupolichas* stage.
5. Echinolichadinae stage.
6. Homolichadinae stage.
7. *Trimerolichas* stage.
8. *Tetralichas* stage.
9. *Amphilichas* stage.
10. *Platylichas* stage.
11. *Hemiarges* stage.
12. *Euarges* stage.
13. *Craspedarges* stage.
14. *Trochurus* stage.
15. *Dicranogmus* stage.
16. *Richterarges* stage.
17. *Diplolichas* stage.
18. *Dicranopeltis* stage.

terior lobe produced in a proboscis-like projection.

Range: Silurian, North America.

Subfamily PLATYLICHADINAE Phleger, n. subfam.

Trochuridae with complete fourth lateral glabellar furrows. Third lateral lobes fused with fixed cheeks. *Metopolichas-Lichas* type of pygidium.

Genus PLATYLICHAS Gürich

Figures 73, 74

Platylichas GÜRICH, *1901*, p. 522.

Genotype: *Lichas margaritifer* Nieszkowski (1857, p. 568, pl. 1, fig. 15).

Platylichadinae with complete longitudinal furrows. Pygidium with two anterior pairs of ribs discrete, and a notch on the postaxial border; axial lobe with three furrows and narrowing posteriorly.

Range: Middle and Upper Ordovician, Silurian, Europe.

Genus AUTOLOXOLICHAS Phleger, n. gen.

Figure 78

Genotype: *Lichas st.-mathiae* Schmidt (1885, p. 115, pl. 5, figs. 11–16).

Differs from *Platylichas* in lacking the continuation of the longitudinal furrows from the third to the fourth lateral furrows.

Range: Middle Ordovician, Europe.

Genus LINGUCEPHALICHAS Phleger n. gen.

Figures 79, 81

Genotype: *Platylichas planifrons* Warburg (1925, pp. 263–273, pl. 6, figs. 11–12, 14–23).

Differs from *Platylichas* in having a tongue-shaped projection on the anterior part of the cephalon.

Range: Upper Ordovician, Europe.

Genus METALICHAS Reed, 1902

Reed (1902) erected the genus *Metalichas*, with *Lichas cicatricosus* Schmidt (not Loven) as the type species. He included also *L. st.-mathiae* Schmidt, *L. hibernicus* Portlock, and *L. aequalis* Tornquist. The validity of this genus is very doubtful inasmuch as no complete specimen of the type, to the knowledge of the writer, has been found, and the association, of the pygidium and cephalon is doubtful. The cephalon differs in no respect from that of *Platylichas* and the pygidium is identical with that of *Tetralichas*. The pygidia and cranidia of *Lichas cicatricosus* described by Schmidt were found at different localities and correlation between the two parts is on the basis of ornamentation. As pointed out by Warburg (1925), this criterion is not necessarily a satisfactory one. Loven's original specimen of *L. cicatricosus* is a pygidium similar to that of *Platylichas margaritifer* (Schmidt) and is not of the *Tetralichas* type. The pygidium figured by Loven and the cranidium figured by Schmidt agree closely with that of *Platylichas;* also, it seems plausible that the pygidium figured by Schmidt belongs to *Tetralichas*. Therefore, there appears to be no real basis for the genus *Metalichas*.

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NEW GENERA AND SPECIES OF OZARKIAN AND CANADIAN BRACHIOPODS

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ABSTRACT

This paper makes available immediately the new systematic units described in a monograph on Ozarkian and Canadian brachiopods now awaiting publication. It is intended to present particularly the genera and species, but all together 1 suborder, 8 families, 6 subfamilies, 33 genera, 64 species, and 12 combinations are proposed. Other systematic units are listed where desirable to indicate relationships.

Ancient brachiopods have always been a profitable and interesting source of study to the geologist, profitable by virtue of their use in stratigraphy and interesting because they shed some light on the devious course of evolution. The appearance of Walcott's great study of the Cambrian Brachiopoda gave the world its first comprehensive view of the most ancient members of this class. Between the Cambrian and Ordovician rocks, however, lies a great sequence of limestones and other sediments containing many brachiopods, of which Walcott had only a faint knowledge and which paleontologists have largely neglected. For many years this difficult ground, the Ozarkian and Canadian, has interested the senior author, who, together with some of his colleagues on the United States Geological Survey, has brought together from it a vast collection of fossils from all parts of the United States.

The brachiopods of this collection are the subject of a forthcoming memoir by the authors. In it there have been recognized 66 genera containing more than 330 species. Before the inception of the work perhaps 170 species of brachiopods, distributed among about 24 genera, were known from Ozarkian and Canadian rocks. The writers thus have more than doubled the number of genera and have nearly doubled the number of species. However, even the present work must be regarded in the nature of a beginning only, because there are thousands of feet of Ozarkian and Canadian strata and miles of territory still to be searched.

The memoir on the Ozarkian and Canadian brachiopods cannot appear, even under the most favorable circumstances, for more than a year. The authors have therefore felt it both wise and necessary to publish a digest of the new genera and the commoner new species, in order that these names may be available to other workers interested in brachiopod evolution and stratigraphy.

Acknowledgments.—Throughout their work the authors have been aided by many institutions and individuals to

whom acknowledgment will be made in the memoir, but the writers wish here gratefully to record their indebtedness to the Geological Society of America, whose generous grant from the Penrose Bequest has made possible the completion of the large memoir and of this digest of new genera and species.

The manuscript of the paper was received by the editor July 13, 1936.

New systematic units proposed in this paper

Suborder:

Syntrophioidea (p. 627)

Families:

Anomalorthidae (p. 622)
Eostrophiidae (p. 627)
Hesperonomiidae (p. 621)
Orthidiellidae (p. 621)
Syntrophopsidae (p. 630)
Taffiidae (p. 625)
Tetralobulidae (p. 627)
Tritoechiidae (p. 624)

Subfamilies:

Leptellininae (p. 626)
Mesonomiinae (p. 627)
Palaeostrophiinae (p. 627)
Syntrophiinae (p. 631)
Tritoechiinae (p. 624)
Xenelasminae (p. 631)

Genera:

Anomalorthis (p. 622)
Apheoörthis (p. 620)
Aporthophyla (p. 625)
Conodiscus (p. 619)
Desmorthis (p. 624)
Diaphelasma (p. 629)
Diparelasma (p. 623)
Discotreta (p. 619)
Eostrophia (p. 627)
Glyptotrophia (p. 627)
Goniotrema (p. 626)
Hesperonomia (p. 621)
Hesperonomiella (p. 622)
Hesperostrophia (p. 630)
Idiostrophia (p. 631)
Leptellina (p. 626)
Mesonomia (p. 627)
Nanorthis (p. 621)
Neostrophia (p. 631)
Oligorthis (p. 624)
Orthidiella (p. 621)
Oxlosia (p. 619)
Palaeostrophia (p. 627)
Palinorthis (p. 625)
Plectotrophia (p. 627)
Punctolira (p. 628)
Rhysostrophia (p. 630)
Syntrophopsis (p. 630)
Tetralobula (p. 628)
Toquimia (p. 626)
Tritoechia (p. 624)
Xenelasma (p. 631)
Xenorthis (p. 620)

Species:

Anomalorthis oklahomensis (p. 622)
Anomalorthis utahensis (p. 622)
Apheoörthis bella (p. 620)
Apheoörthis emmonsi (p. 620)
Apheoörthis ornata (p. 620)
Aporthophyla typa (p. 625)
Archaeorthis canadensis (p. 620)
Archaeorthis elongata (p. 620)
Archaeorthis glomerata (p. 621)
Billingsella corrugata (p. 619)
Billingsella perfecta (p. 619)
Clarkella mcgerriglei (p. 628)
Desmorthis nevadensis (p. 624)
Diaphelasma breviseptatum (p. 629)
Diaphelasma complanatum (p. 629)
Diaphelasma pennsylvanicum (p. 629)
Diaphelasma quebecense (p. 629)
Diparelasma typicum (p. 623)
Elkania alaskensis (p. 618)
Finkelnburgia bellatula (p. 622)
Finkelnburgia buttsi (p. 623)
Finkelnburgia cullisoni (p. 623)
Finkelnburgia missouriensis (p. 623)
Finkelnburgia scenidioides (p. 623)
Finkelnburgia subaequiradiata (p. 623)
Finkelnburgia virginica (p. 623)
Glyptotrophia imbricata (p. 627)
Goniotrema perplexa (p. 626)
Hesperonomia antelopensis (p. 622)
Hesperonomia crassa (p. 621)
Hesperonomia louisensis (p. 622)
Hesperonomia planidorsalis (p. 621)
Hesperostrophia obscura (p. 630)
Idiostrophia perfecta (p. 631)
Leptella nevadensis (p. 626)

Leptellina tennesseensis (p. 626)
Neostrophia subcostata (p. 631)
Oligorthis arbucklensis (p. 624)
Orthidiella longwelli (p. 621)
Palinorthis cloudi (p. 626)
Plectotrophia bridgei (p. 627)
Pomatotrema oklahomense (p. 624)
Punctolira punctolira (p. 628)
Rhysostrophia nevadensis (p. 630)
Rhysostrophia occidentalis (p. 630)
Rhysostrophia transversa (p. 630)
Schizambon australis (p. 619)
Syntrophia longaeva (p. 631)
Syntrophina carinifera (p. 628)
Syntrophina gibbosa (p. 629)
Syntrophina missouriensis (p. 629)
Syntrophopsis cassinensis (p. 630)
Syntrophopsis magna (p. 630)
Taffia westgatei (p. 625)
Tetralobula delicatula (p. 628)
Tetralobula imbricata (p. 628)
Tetralobula quadrata (p. 628)
Tetralobula transversa (p. 628)
Toquimia kirki (p. 626)
Tritoechia delicatula (p. 625)
Tritoechia hemipyramidata (p. 625)
Trtoechia quebecensis (p. 625)
Xenelasma syntrophioides (p. 631)
Xenorthis jonasae (p. 620)

Combinations:

Anomalorthis lonensis (Walcott)—*Orthis l.* (p. 622)
Apheoörthis lineocostata (Walcott)—*Eoörthis l.* (p. 620)
Apheoörthis melita (Hall and Whitfield)—*Leptaena m.* (p. 620)
Conodiscus burlingi (Kobayashi)—*Acrothele b.* (p. 619)
Diparelasma elegantula (Butts)—*Deltatreta e.* (p. 624)
Discotreta levisensis (Walcott)—*Acrothele l.* (p. 619)
Eostrophia cambria (Walcott)—*Syntrophia c.* (p. 627)
Finkelnburgia wemplei (Cleland)—*Dalmanella (Orthis) w.* (p. 622)
Glyptostrophia jasperensis (C. H. Kindle)—*Huenella j.* (p. 627)
Hesperonomiella porcias (Walcott)—*Protorthis p.* (p. 622)
Mesonomia iophon (Walcott)—*Eoörthis i.* (p. 627)
Nanorthis hamburgensis (Walcott)—*Orthis h.* (p. 621)
Palaeostrophia orthia (Walcott)—*Syntrophia o.* (p. 627)
Plectotrophia alata (Walcott)—*Syntrophia a.* (p. 627)
Tritoechia dice (Walcott)—*Billingsella d.* (p. 625)
Tritoechia typica (Ulrich)—*Deltatreta t.* (p. 625)
Xenorthis stosei (Bassler)—*Strophomena s.* (p. 620)

SYSTEMATIC DESCRIPTIONS

Order ATREMATA Beecher
Superfamily OBOLACEA Schuchert, 1896
Family OBOLIDAE King, 1846

Lingulella Salter, 1866; *Obolus* Eichwald, 1829; *Paterula* Barrande, 1879; *Westonia* Walcott, 1901.

Family ELKANIIDAE Walcott and Schuchert, 1908

Elkania Ford, 1886; *Broeggeria* Walcott, 1902.

ELKANIA ALASKENSIS Ulrich and Cooper, n. sp.

In its narrow and more elevated umbones *Obolus hamburgensis* Kobayashi (Jap. Jour. Geol. Geogr., vol. 12, nos. 3–4, p. 43, pl. 8, figs. 8–11, 1935) differs from *O. hamburgensis* Walcott (see *Nanorthis*, p. 000) and is here referred to *Elkania*. Syntypes, U. S. Nat. Mus. 92819*a–c*.

Superfamily LINGULACEA Waagen, 1885
Family LINGULIDAE Gray, 1840

Lingula Bruguiere, 1792.

Order NEOTREMATA Beecher
Superfamily SIPHONOTRETACEA Walcott and Schuchert, 1908
Family SIPHONOTRETIDAE Kutorga, 1848

Siphonotreta DeVerneuil, 1845; *Schizambon* Walcott, 1884.

SCHIZAMBON AUSTRALIS Ulrich and Cooper, n. sp.

Large for pre-Ordovician members of the genus, subcircular or longitudinally elliptical, with small elliptical foramen which is not extended forward; valves gently convex, ornamented by fine, elevated costellae, about 11 in 1 mm. at the front. Muscular and pallial marks strongly impressed. Differs from *S. typicalis* in the more posterior position of the foramen and the strong even costellation of the valves. Upper Ozarkian (with *Leiostegium*), at Cajas, about 15 miles west of Humahuaca, Jujuy province, Argentina. Syntypes, U. S. Nat. Mus. 92821*a–r*. Ventral valve 92821*b* is 6 mm. long, 5 mm. wide; dorsal valve 92821*a* is 5.5 mm. long, 5.3 mm. wide.

Superfamily ACROTRETACEA Schuchert, 1896
Family ACROTRETIDAE Schuchert, 1893
Subfamily ACROTHELINAE Walcott and Schuchert, 1908

CONODISCUS Ulrich and Cooper, n. gen.

Like *Acrothele* but with a conical dorsal valve. Genotype, *Acrothele burlingi* Kobayashi (Jap. Jour. Geol. Geog., vol. 12, nos. 3–4, p. 45, pl. 8, figs. 21, 22, 1935). Syntypes, U. S. Nat. Mus. 92829*a*.

DISCOTRETA Ulrich and Cooper, n. gen.

Biconical, foramen bounded by lateral folds. Differs from *Acrothele* in its external form, modified foramen. In the dorsal valve there are two elongate divergent muscle scars. Genotype, *Acrothele levisensis* Walcott (Smithson. Misc. Coll., vol. 53, no. 3, p. 85, pl. 8, fig. 13, 1908). Hypotypes, U. S. Nat. Mus. 92832*a–e*.

Subfamily ACROTRETINAE Matthew, 1903

Acrotreta Kutorga, 1848.

Superfamily DISCINACEA Waagen, 1885
Family TREMATIDAE Schuchert, 1893

OXLOSIA Ulrich and Cooper, n. name

For *Eunoa* Clarke, 1902 (not Malmgren, 1867) (New York State Mus., Bull. 52, p. 606, 1902).

Order PROTREMATA Beecher
Suborder ORTHOIDEA Schuchert and Cooper, 1931
Superfamily ORTHACEA Walcott and Schuchert, 1908
Family BILLINGSELLIDAE Schuchert and Cooper, 1931
Subfamily BILLINGSELLINAE Walcott and Schuchert, 1908

Billingsella Hall 1892.

BILLINGSELLA CORRUGATA Ulrich and Cooper, n. sp.

Large, transverse, with sharply angular cardinal extremities. Differing from known species in the possession of strong concentric lamellae. Upper Cambrian (Fort Sill) limestone, Fort Sill, Oklahoma. Syntypes, U. S. Nat. Mus. 91442*a–m*. Ventral valve 91442*i* is 11.5 mm. long, 12 mm. wide, hinge 14.5 mm.; dorsal valve 91442*j* is 9 mm. long, 12.5 mm. wide, hinge 15.5 mm.

BILLINGSELLA PERFECTA Ulrich and Cooper, n. sp.

Often misidentified as *B. coloradoensis* (Shumard), from which it differs in smaller size, rounded cardinal extremities, deeper dorsal sulcus, and less prominent fold. Yogo limestone, Grand Teton, south of Muskrat Lake, Teton Creek, Idaho-Wyoming State line. Syntypes, U. S. Nat. Mus. 91441*a–t*. Ventral valve 91441*h* is 11 mm. long, 11.5 mm. wide, hinge 11.25 mm.; dorsal valve

91441*j* is 8 mm. long, 11.5 mm. wide, hinge 11 mm.

XENORTHIS Ulrich and Cooper, n. gen.

Like *Billingsella*, but with a strong dorsal fold, elevated ventral diductor track and rudimentary or no dental plates. Genotype, *Strophomena stosei* Bassler (Maryland Geol. Survey, Cambrian and Ordovician, p. 250, pl. 37, figs. 1–4, 1919). Syntypes, U. S. Nat. Mus. 66164; Hypotypes, U. S. Nat. Mus. 92836*a–c*.

XENORTHIS JONASAE Ulrich and Cooper, n. sp.

Differs from *X. stosei* (Bassler) in its more robust form, deeper valves, and greater prominence of the fold and sulcus. Frederick limestone, quarry on south side Libertytown road in Ceresville, about 4 mi. N. of Frederick, Maryland. Holotype, U. S. Nat. Mus. 92835*a*, is 15 mm. long, 17.5 mm. wide; paratypes, U. S. Nat. Mus. 92835*b–f*.

Subfamily EOÖRTHINAE Walcott, 1908

APHEOÖRTHIS Ulrich and Cooper, n. gen.

An aberrant eoörthid, fascicostellate, with pseudospondylium. Genotype, *Eoörthis lineocosta* Walcott (Smithson. Misc. Coll., vol. 67, no. 9, p. 508, pl. 115, figs. 3, 4 (not 5), 1924). Syntypes, U. S. Nat. Mus. 69747, 69748; hypotypes, 91187*a–h*.

APHEOÖRTHIS BELLA Ulrich and Cooper, n. sp.

Differs from *A. lineocosta* (Walcott) in its wider hinge, acute cardinal extremities, deeper valves, and obscurer facsiculation of the costellae. Manitou limestone, 50 feet above granite, north of Manitou, Colorado. Syntypes, U. S. Nat. Mus. 91177*a–e*. Ventral valve 91177*d* is 7 mm. long, 8.5 mm. wide, hinge 9.5 mm.; dorsal valve 91177*b* is 8 mm. long, 10.5 mm. wide, hinge 10 mm.

APHEOÖRTHIS EMMONSI Ulrich and Cooper, n. sp.

Differs from *A. lineocosta* (Walcott) in its transverse form and lack of fasciculation. Sawatch limestone, Dyer Mountain, 5 miles east of Leadville, Colorado. Syntypes, U. S. Nat. Mus. 91182*a–h*. Ventral valve 91182*d*, 10 mm. long, 14 mm. wide, hinge 10 mm.; dorsal valve 91182*c*, 8.5 mm. long, 11.5 mm. wide, hinge 10 mm.

APHEOÖRTHIS ORNATA Ulrich and Cooper, n. sp.

Resembles *A. melita* (Hall and Whitfield) (*Leptaena m.*, U. S. Geol. Explor. 40th Par., vol. 4, pt. 2, p. 208, pl. 1, figs. 13, 14, 1877), but differs in its more convex valves, smaller size, and stronger fascicles. Arbuckle (Signal Mountain) limestone, west side of U. S. highway 77, NW.$\frac{1}{4}$ NW.$\frac{1}{4}$ sec. 18, T. 2 S., R. 2 E., Ardmore quad., Oklahoma, Holotype, U. S. Nat. Mus. 92899; paratypes, U. S. Nat. Mus. 92900*a–g*.

Family ORTHIDAE Woodward, 1852
Subfamily ORTHINAE Waagen, 1884

Orthis Dalman, 1828; *Archaeorthis* Schuchert and Cooper, 1931.

ARCHAEORTHIS CANADENSIS Ulrich and Cooper, n. sp.

Suggests *A. electra* (Billings), but differs in its coarser costellae, more nearly circular outline, and less carinate ventral valve. Hastings Creek formation (100 feet below top), three-fourths of a mile a little south of east of Philipsburg, Quebec. Syntypes, U. S. Nat. Mus. 91444*a–g*. Ventral valve 91444*a*, 10 mm. long, 10 mm. wide; dorsal valve 91444*b*, 9.5 mm. long, 11.5 mm. wide.

ARCHAEORTHIS ELONGATA Ulrich and Cooper, n. sp.

Small, a little longer than wide, lateral margins concave anterior to hinge, front margin rounded. Ventral valve strongly convex, umbo swollen, lateral slopes steep. Dorsal valve gently convex in

lateral profile, marked medially by a shallow sulcus. About 34 costellae at front of valve. Differs from *A. electra* (Billings) by its more elongate form and smaller size. Holotype, U. S. Nat. Mus. 91456, 5.5 mm. long, 5 mm. wide, hinge 5 mm., thickness 3 mm. Upper Pogonip, west front Antelope Range, 2½ mi. south of Ninemile Canyon, Roberts Mountains quad., Nevada. Paratypes, U. S. Nat. Mus. 91457*a–d*.

ARCHAEORTHIS GLOMERATA Ulrich and Cooper, n. sp.

Small, subcircular; ventral valve strongly convex, medially swollen, with steep lateral slopes. Dorsal valve gently convex, deeply sulcate. Differs from *A. electra* Billings and *A. canadensis* Ulrich and Cooper by its coarser ornamentation. Multicostellate, 3 to 4 costellae in 2 mm. Luke Hill formation, about 1 mile a little south of east of Philipsburg, Quebec. Syntypes, U. S. Nat. Mus. 91462*a–e;* 92461*a–e;* 91460; 91549*a*, *b*. Ventral valve 91461*e*, 10 mm. long, 11 mm. wide; dorsal valve 91461*d*, 9 mm. long, 10 mm. wide.

NANORTHIS Ulrich and Cooper, n. gen.

Small, subcircular, fascicostellate, dorsal interior like *Archaeorthis*, but ventral valve without muscular callosity. Genotype, *Orthis hamburgensis* Walcott (U. S. Geol. Survey Mon. 8, p. 73, pl. 11, figs. 5, 5*a*, 1884). Syntypes, U. S. Nat. Mus. 17259*a*, *b;* hypotypes, U. S. Nat. Mus. 91110*a–j*.

Family ORTHIDIELLIDAE Ulrich and Cooper, n. fam.

Internal characters of *Orthidiella* and *Orthidium*, with the cardinal process and brachiophores united by shell substance.

Orthidium Hall and Clarke, 1892.

ORTHIDIELLA Ulrich and Cooper, n. gen.

Like *Orthidium* internally but with simple costellae and dalmanelloid form. Genotype, *Orthidiella longwelli* Ulrich and Cooper.

ORTHIDIELLA LONGWELLI Ulrich and Cooper, n. sp.

Small, a little wider than long, cardinal extremities acute; ventral valve convex, carinate to front third of valve, lateral areas steep; dorsal valve strongly convex, median sulcus deep and wide. Eight costellae in 1 mm. at front of valve. Holotype, U. S. Nat. Mus. 91299, 7 mm. long, 7.5 mm. wide, 4 mm. thick, hinge 8 mm.; paratypes U. S. Nat. Mus. 91300*a–g*. Pogonip formation near base of first ridge east of Frenchman Flat, Las Vegas Quad, Nevada.

Family HESPERONOMIIDAE Ulrich and Cooper, n. fam.

Internal features of the dorsal valve of *Hesperonomia*.

HESPERONOMIA Ulrich and Cooper, n. gen.

Rafinesquinoid in form but not pseudopunctate, costellate; orthoid ventral muscles, and cardinalia; chilidial plates present, deltidium absent; cardinal process simple. Genotype, *Hesperonomia planidorsalis* Ulrich and Cooper.

HESPERONOMIA PLANIDORSALIS Ulrich and Cooper, n. sp.

Shell a little wider than long, ventral valve gently convex, dorsal valve gently concave. Three costellae in 1 mm. at front of valve. Holotype, U. S. Nat. Mus. 91559*b*, 10 mm. long, 11.5 mm. wide, width of hinge 13 mm.; paratype, U. S. Nat. Mus. 91559*a*. Sarbach formation, Fossil Mountain, Lake Louise, Alberta.

HESPERONOMIA CRASSA Ulrich and Cooper, n. sp.

Differs from *H. planidorsalis* Ulrich and Cooper in its more transverse form, and coarser ornamentation, there being 8 to 10 costellae in 5 mm. at the front margin. Sarbach formation, Fossil Mountain, Lake Louise, Alberta, Canada.

Syntypes U. S. Nat. Mus. 91499*a–f;* 91550*a–e;* 91551*a–c.* Ventral valve 91551*b*, 14 mm. long, 18 mm. wide; dorsal valve 91551*c*, 11 mm. long, 14.5 mm. wide.

HESPERONOMIA LOUISENSIS Ulrich and Cooper, n. sp.

Resembles *H. planidorsalis* Ulrich and Cooper in ornamentation but is more transverse and with about 100 costellae. Sarbach formation, Fossil Mountain, Lake Louise, Alberta, Canada. Syntypes, U. S. Nat. Mus. 91561*a–c;* 91563*a–k.* Ventral valve 91561*c*, 9.5 mm. long, 12.5 mm. wide, 13 mm. hinge; dorsal valve 91561*a*, 12 mm. long, 17.5 mm. wide, 17 mm. hinge.

HESPERONOMIA ANTELOPENSIS Ulrich and Cooper, n. sp.

Differs from *H. louisensis* Ulrich and Cooper in its less numerous costellae (about 80), more carinate ventral valve, deeper dorsal sulcus and more quadrate form. Syntypes, U. S. Nat. Mus. 91491, 91492*a, b;* 91493*a–h.* Ventral valve 91493*b*, 13 mm. long, 15 mm. wide, hinge 15 mm.; dorsal valve 91493*a*, 11 mm. long, 14 mm. wide, hinge 14.5 mm. Pogonip-formation, Antelope Mts., 2½ miles south of Ninemile Canyon, Roberts Mountains quadrangle, Nevada.

HESPERONOMIELLA Ulrich and Cooper, n. gen.

Like *Hesperonomia* internally, but with a convex dorsal valve. Genotype, *Protorthis porcias* Walcott (Smithson. Misc. Coll., vol. 67, no. 9, p. 504, pl. 111, fig. 11 only, 1924). Lectotype (Ulrich and Cooper) U. S. Nat. Mus. 69714.

Family DINORTHIDAE Schuchert and Cooper, 1931

Valcourea Raymond, 1911.

Family ANOMALORTHIDAE Ulrich and Cooper, n. fam.

Having a sessile spondylium, rudimentary deltidium, and cardinalia like those of *Orthis.*

ANOMALORTHIS Ulrich and Cooper, n. gen.

Resembles *Herbertella* in profile, but has sessile spondylium; short, imperforate deltidium; orthoid cardinalia; finely costellate exterior. Genotype, *A. utahensis* Ulrich and Cooper.

ANOMALORTHIS UTAHENSIS Ulrich and Cooper, n. sp.

Rather large, 5 or 6 costellae in 1 mm. at front; ventral valve hemiconical, interarea broad, strongly apsacline; delthyrium wide; dorsal valve gently convex, fold low. Holotype, U. S. Nat. Mus. 91284, 16 mm. long, 20 mm. wide, hinge 19.5 mm. Paratypes, U. S. Nat. Mus. 91283*a–f.* Swan Peak formation, 1 mile west of Ibex Post Office, Confusion Range, Utah.

ANOMALORTHIS OKLAHOMENSIS Ulrich and Cooper, n. sp.

Suggests *A. lonensis* (Walcott) (*Orthis l.*, U. S. Geol. Survey, Mon. 8, p. 74, pl. 11, figs. 6, 6*a*, 1884), but differs in having finer ornamentation, a strongly procline ventral interarea, less swollen ventral valve with shallower sulcus. Oil Creek formation, NE.¼ sec. 22, T. 2 S., R. 1 E., 4 or 5 miles due north of Glenn; and 4 miles north of Springer, Oklahoma. Syntypes, U. S. Nat. Mus. 92854*a–e*, 92855. Ventral valve 92854*a*, 8.5 mm. long, 13 mm. wide, hinge 13 mm.; dorsal valve 92854*b*, 10.5 mm. long, 13.5 mm. wide, hinge 13.5 mm.

Family FINKELNBURGIIDAE Schuchert and Cooper, 1931

Orusia Walcott, 1905; *Finkelnburgia* Walcott, 1905.

FINKELNBURGIA BELLATULA Ulrich and Cooper, n. sp.

Very close to *F. wemplei* (Cleland) (*Dalmanella* (*Orthis*) *w.*, Bull. Am.

Paleontology, vol. 13, p. 129, pl. 17, figs. 10–13, 1900), but differs in its more transverse form. Ventral valve 91364*d*, 7.5 mm. long, 8.5 mm. wide, hinge 7 mm.; dorsal valve 91364*l*, 7 mm. long, 10 mm. wide. Gasconade formation, Huzzah Creek, 10 miles east of Steeleville, Missouri. Syntypes, U. S. Nat. Mus. 91364*a–l*.

FINKELNBURGIA BUTTSI Ulrich and Cooper, n. sp.

Large for the genus, transverse, with angular cardinal extremities. Ventral valve full in middle, beak pointed, lateral slopes gently concave. Dorsal valve strongly convex, median sulcus narrow and shallow. Spondylium short and wide, costellae unequal, variable, cancellated by strong concentric growth lines. Differs from *F. armanda* (Billings) in ornamentation. Chepultepec formation, 2.1 mi. northwest of Quicksburg, Woodstock quad., Virginia. Holotype, U. S. Nat. Mus. 91380*h* (ventral valve), 7 mm. long, 9 mm. wide, hinge 12 mm.; paratypes, U. S. Nat. Mus. 91380*a–g*, *i–l*.

FINKELNBURGIA CULLISONI Ulrich and Cooper, n. sp.

Like *F. armanda* (Billings) in size, possessing a broad shallow spondylium, but proportionately not so wide, and with numerous hollow costellae. Top of Arbuckle limestone (Jefferson City horizon), Horseshoe Ranch, sec. 9, T. 1 N., R. 5 E., Oklahoma. Holotype, U. S. Nat. Mus. 92858*b* (ventral valve), 14 mm. long, 17 mm. wide, hinge 14 mm.; paratypes, U. S. Nat. Mus. 92858*a*, *c–n*.

FINKELNBURGIA MISSOURIENSIS Ulrich and Cooper, n. sp.

Suggesting *F. bellatula* Ulrich and Cooper but differing in the possession of a deep dorsal sulcus. Eminence formation, 1 mile N.N.E. of Eminence, Missouri. Syntypes, U. S. Nat. Mus. 91389*a–h*. Syntype (ventral), 91389*c*, 8 mm. long, 10 mm. wide; syntype (dorsal), 91389*c*, 6 mm. long and 8 mm. wide.

FINKELNBURGIA SCENIDIOIDES Ulrich and Cooper, n. sp.

Externally suggesting *F. missouriensis* Ulrich and Cooper, but with acute cardinal extremities; internally like *F. cullisoni*, with a broad flat spondylium. Arbuckle limestone (2086 feet below top), sec. 19, T. 2 S., R. 2 E., Carter County, Oklahoma. Holotype, U. S. Nat. Mus. 92984*d*, 5 mm. long, 5.5 mm. wide, hinge 6 mm.; paratypes, U. S. Nat Mus. 92984*a–c*, *e–i*.

FINKELNBURGIA VIRGINICA Ulrich and Cooper, n. sp.

Resembling *F. buttsi* Ulrich and Cooper in size, but more evenly costellate and with fuller valves. Longview formation, 2.8 miles northwest of Middletown, Winchester quad., Virginia. Syntypes, U. S. Nat. Mus. 91410*a–f*. Ventral valve 91410*c*, 9.5 mm. long, 12 mm. wide, hinge 11 mm.; dorsal valve 91410*a*, 9 mm. long, 12 mm. wide.

FINKELNBURGIA SUBAEQUIRADIATA Ulrich and Cooper, n. sp.

Differs from other species of the genus here described by its fine, even costellae, 4 to 1 mm., and strongly convex valves. Morgan Corners formation, one-third mile a little south of east of Philipsburg, Quebec. Syntypes, U. S. Nat. Mus. 91408*a–j*. Ventral valve 91408*f*, 10 mm. long, 12.3 mm. wide, hinge 9 mm.; dorsal valve 91408*d*, 8.7 mm. long, 11 mm. wide, hinge 9 mm.

DIPARELASMA Ulrich and Cooper, n. gen.

Dalmanelloid externally, impunctate, finely costellate; ventral interior with pseudospondylium; dorsal interior with narrowly convergent brachiophore plates. Differs from *Finkelnburgia* in outlines and in erect position of brachiophore plates. Genotype, *D. typicum* Ulrich and Cooper.

DIPARELASMA TYPICUM Ulrich and Cooper, n. sp.

Subcircular, narrow-hinged, lenticular

in profiles; 5 costellae in 1 mm. at front. Ventral valve gently convex, with front half flattened; dorsal valve evenly and gently convex, with sulcus narrow, lost near front. Pseudospondylium well-developed in adults. Differs from *D. elegantula* (Butts) (*Deltatreta e.*, Geol. Alabama, pl. 18, figs. 18–20, not fig. 27, 1926) by its rounder outline and more numerous costellae. Syntypes, U. S. Nat. Mus. 91261*a–f*, 91262*a–f*, 91267*a*, *b*. Upper Arbuckle limestone, SW$\frac{1}{4}$ sec. 2, T. 1 S., R. 1 W., about 4 miles east of Hennepin; NW.$\frac{1}{4}$ sec. 36, T. 3 S., R. 4 E., Tishomingo quad., Oklahoma. Ventral valve 91261*d*, 8 mm. long, 8.5 mm. wide; dorsal valve 91261*b*, 8.5 mm. long, 8.5 mm. wide.

Family PLECTORTHIDAE Schuchert and Cooper, 1931

OLIGORTHIS Ulrich and Cooper, n. gen.

Resembles *Desmorthis* internally, but lacks cardinal process and deltidium. Genotype, *O. arbucklensis* Ulrich and Cooper.

OLIGORTHIS ARBUCKLENSIS Ulrich and Cooper, n. sp.

Small, semielliptical, finely costellate, 5 costellae in 1 mm. at front. Ventral valve most convex posteriorly, flattened at front, interarea strongly apsacline; dorsal valve flatly convex, umbo and beak inconspicuous. Canadian, one-fourth mile west of Ardmore-Davis road (U. S. Highway 77), west of cattle underpass, sec. 18, T. 2 S., R. 2 E., Ardmore quad. Oklahoma. Syntypes, U. S. Nat. Mus. 91340*a–f*. Ventral valve 91340*e*, 4.5 mm. long, 7 mm. wide, hinge 6.5 mm.; dorsal valve 91340*c*, 4.5 mm. long, 7 mm. wide, hinge 6.5 mm.

DESMORTHIS Ulrich and Cooper, n. gen.

Resembling *Doleroides* externally, but with a deltidium and thin septum-like cardinal process; brachiophore plates plectorthoid. Genotype, *Desmorthis nevadensis* Ulrich and Cooper.

DESMORTHIS NEVADENSIS Ulrich and Cooper, n. sp.

Small, biconvex, wider than long, 12–14 costellae in 5 mm. at front; costellae swollen, hollow; ventral valve gently convex, front flattened. Dorsal valve flatly convex, front half sulcate. Dental plates strong. Holotype, U. S. Nat. Mus. 91344*a*, length 4 mm., width 5 mm. Upper Pogonip formation, west end of Lone Mountain, 18 miles northwest of Eureka, Nevada; paratypes, U. S. Nat. Mus. 91344*b–h*; 91342*a–d*.

Suborder CLITAMBONOIDEA Öpik, 1934

Superfamily CLITAMBONACEA Schuchert, 1929

Family TRITOECHIIDAE Ulrich and Cooper, n. name

Replaces family Deltatretidae (see under *Polytoechia*).

TRITOECHIINAE Ulrich and Cooper, n. subfam.

Tritoechiidae with discrete dental plates.

Pomatotrema Ulrich and Cooper, 1932.

POMATOTREMA OKLAHOMENSE Ulrich and Cooper, n. sp.

Differs from *P. murale* Ulrich and Cooper, with which it occurs, by its thinner shell, more delicate internal structures, and more transverse form, and nearly complete absence of a subperipheral rim. Arbuckle limestone, S W.$\frac{1}{4}$ sec, 2. T. 1 S., R. 1 W., about 4 miles east of Hennepin, Okla. Syntypes, U. S. Nat. Mus. 91703*a–g*. Ventral valve 91703*b*, 9.5 mm. long, 12.5 mm. wide; dorsal valve 91703*f*, 9.5 mm. long, 12.5 mm. wide.

Genus TRITOECHIA Ulrich and Cooper, n. gen.

Like *Polytoechia* but with discrete dental plates in the ventral valve.

Genotype, *Deltatreta typica* Ulrich in Schuchert and Cooper (Peabody Mus. Nat. Hist., Mem., vol. 4, pt. 1, p. 206, pl. 6, figs. 10, 14, 19, 30, 1932).

TRITOECHIA DELICATULA Ulrich and Cooper, n. sp.

Differs from *T. typica* (Ulrich) by its smaller size, shorter and more curved interarea, and lack of swollen, hollow costellae. Syntypes, U. S. Nat. Mus. 91715*a–c*, 91716*a–i*. Ventral valve 91716*c*, 7.5 mm. long, 9 mm. wide; dorsal valve 91716*g*, 8.5 mm. long, 12 mm. wide. Arbuckle limestone, 3½ miles east of Nebo, Oklahoma.

TRITOECHIA HEMIPYRAMIDATA Ulrich and Cooper, n. sp.

Small hemipyramidal, ventral valve with elongate interarea, delthyrium, narrow; dorsal valve moderately convex, marked medially by a shallow sulcus. Multicostellate. Dental plates almost obsolete. Differs from other described species by its small size and elongate ventral valve. Sarbach formation, northeast shoulder of Fossil Mountain, Lake Louise, Alberta. Syntypes, U. S. Nat. Mus. 91730, 91731*a–l*. Ventral valve 91731*j*, 5.5 mm. long, 8 mm. wide; dorsal valve 91731*g*, 6 mm. long and 7.5 mm. wide.

TRITOECHIA QUEBECENSIS Ulrich and Cooper, n. sp.

Differs from *T. dice* (Walcott) (*Billingsella d.*, U. S. Nat. Mus., Proc., vol. 28, p. 234, 1905) in its more elongate valves and stronger, unequal costellae. About 100 feet below top of Hastings Creek formation, on north side of road from Philipsburg to St. Armand, three-fourths of a mi. southeast of Philipsburg. Syntypes, U. S. Nat. Mus. 91741 *a–g*.

Subfamily POLYTOECHIINAE Öpik, 1934

Polytoechia Hall and Clarke, 1892 (synonym, *Deltatreta* Ulrich, 1926).

Suborder STROPHOMENOIDEA Öpik, 1934.

Superfamily STROPHOMENACEA Schuchert, 1896

Family TAFFIIDAE Ulrich and Cooper, n. fam.

Dorsal interior orthoid, pseudopunctate; exterior rafinesquinoid and strophomenoid.

Taffia Butts, 1926.

TAFFIA WESTGATEI Ulrich and Cooper, n. sp.

Differs from *T. planoconvexa* Butts by its more concave dorsal valve, shallower but more carinate ventral valve, shorter ventral interarea, and more incurved beak. The subperipheral rim is emarginated posteriorly in the dorsal valve. Yellow Hill formation, north end Ely Springs Range on west side Highland Peak quadrangle, Nevada. Syntypes, U. S. Nat. Mus. 91593*a–e*. Ventral valve 91593*a*, 12 mm. long and 16 mm. wide, hinge 15 mm.; dorsal valve 91593*d*, 12 mm. long and 16.5 mm. wide.

APORTHOPHYLA Ulrich and Cooper, n. gen.

Resembling *Taffia* in shell structure and exteriors but possessing a cardinal process. Genotype, *Aporthophyla typa* Ulrich and Cooper.

APORTHOPHYLA TYPA Ulrich and Cooper, n. sp.

Subquadrate, large, ventral valve gently convex, dorsal valve gently concave, ornamentation as in *Rafinesquina*. Interior as in *Orthis*, with a simple cardinal process. Syntypes, U. S. Nat. Mus. 92866*a–h*. Syntype 92866*c*, 20 mm. long, 25 mm. wide, 3 mm. thick. Upper Pogonip, Ikes Canyon, east side of Toquima Range, Roberts Mountains quad., Nevada.

PALINORTHIS Ulrich and Cooper, n. gen.

Like *Aporthophyla*, but with resupinate valves. Genotype, *Palinorthis cloudi* Ulrich and Cooper.

PALINORTHIS CLOUDI Ulrich and Cooper, n. sp.

Fairly large, like *Strophomena* in outline and shape; costellate, about 6 costellae in 5 mm. Ventral valve gently concave at front, umbo flatly convex; interarea flat, apsacline; deltidium strong; dorsal valve gently convex, umbo concave. Cardinal process large. Holotype, U. S. Nat. Mus. 91582, 17 mm. long, 20 mm. wide, hinge 23.5 mm., 3.5 mm. thick. Upper Pogonip, near base of first ridge east of Frenchman Flat, Las Vegas quad., Nevada.

TOQUIMIA Ulrich and Cooper, n. gen.

Externally like *Rafinesquina*, but with flabellate muscle-scar in ventral valve. In dorsal valve brachiophore plates meet floor of valve; cardinal process simple, ponderous. Genotype, *Toquimia kirki* Ulrich and Cooper.

TOQUIMIA KIRKI Ulrich and Cooper, n. sp.

Large, with flatly convex ventral valve and flat dorsal valve; costellae unequal in size; ventral umbo carinate; dorsal valve sulcate. Interior distinctive, as above. Syntypes U. S. Nat. Mus. 91595*a–f*. Syntype 91595*a*, 24 mm. long, 31 mm. wide. Upper Pogonip, Ikes Canyon, east side Toquima Range, Roberts Mountains quad., Nevada.

Family STROPHOMENIDAE King, 1846

GONIOTREMA Ulrich and Cooper, n. gen.

Externally like *Leptaena* but with elongate ventral muscles. Genotype, *Goniotrema perplexa* Ulrich and Cooper.

GONIOTREMA PERPLEXA Ulrich and Cooper, n. sp.

Concave-convex, suggesting a large *Sowerbyella* in ornamentation but geniculated dorsally about two-thirds the length of the valve from the beak. Finely but distantly costellate. Ventral valve with a shallow median sulcus from umbo to margin; umbo subcarinate; dorsal valve with slight medial fold. Cardinal process bilobed. Holotype, U. S. Nat. Mus. 92872, 15.5 mm. long, 25 mm. wide. Upper Pogonip, Ikes Canyon, east side Toquima Range, Roberts Mountains quad., Nevada.

Family PLECTAMBONITIDAE Kozlowski, 1929

Subfamily SOWERBYELLINAE Öpik, 1930

Sowerbyella Jones, 1928.

Subfamily LEPTELLININAE Ulrich and Cooper, n. subfam.

Cardinal process rudimentary or wanting.

Leptella Hall and Clarke, 1892.

LEPTELLA NEVADENSIS Ulrich and Cooper, n. sp.

Differs from *L. sordida* Billings in having a ventral valve less inflated in the mid-region, with consequent gentler lateral slopes and less deflected cardinal extremities. Upper Pogonip, west front Antelope Range, 2½ mi. south of Ninemile Canyon, Roberts Mountains quad., Nevada. Syntypes, U. S. Nat. Mus. 91332*a–c* Ventral valve 91332*b*, 7.5 mm. long, 8.5 mm. wide; dorsal valve 91332*a*, 8 mm. long, 10 mm. wide.

LEPTELLINA Ulrich and Cooper, n. gen.

Like *Leptelloidea* but with a simple ridgelike cardinal process. Genotype, *Leptellina tennesseensis* Ulrich and Cooper.

LEPTELLINA TENNESSEENSIS Ulrich and Cooper, n. sp.

Fairly large, concavo-convex; cardinal extremities angular and extended; valves geniculated dorsally near the middle, ventral valve with a median fold for length of valve; unequally costellate, two large costellae in 1 mm., with up to four costellae between them. Holotype, U. S. Nat. Mus. 92871, 10 mm. long, 10 mm.

wide at middle, 3.7 mm. thick, hinge 12 mm. wide. Chazyan (Lenoir), one-fourth mile west of Friendsville, Tennessee.

Suborder SYNTROPHIOIDEA Ulrich and Cooper, n. suborder

Family EOSTROPHIIDAE Ulrich and Cooper, n. fam.

Primitive syntrophioids having the interior of *Eostrophia*.

Cambrotrophia
~~EOSTROPHIA~~ Ulrich and Cooper, n. gen.

With external form of *Syntrophina*, but without a spondylium and with rudimentary brachiophore plates. Genotype, *Syntrophia cambria* Walcott (U. S. Geol. Survey, Mon. 51, p. 800, figs. 72*a–d*). Holotype, U. S. Nat. Mus. 52477*a;* paratypes, U. S. Nat. Mus. 57029*a*, 52478, 52477*c*.

Family HUENELLIDAE Schuchert and Cooper, 1931

Subfamily PALAEOSTROPHIINAE Ulrich and Cooper, n. subfam.

Huenellids having dorsally convergent brachiophore plates but no cardinal process.

Huenella Walcott, 1908; *Huenellina* Schuchert and Cooper, 1931.

PALAEOSTROPHIA Ulrich and Cooper, n. gen.

Internally like *Huenella* but exterior smooth. Genotype, *Syntrophia orthia* Walcott (U. S. Nat. Mus., Proc., vol. 29, pp. 11, 12, 1905). Holotype, U. S. Nat. Mus. 52562*a;* paratypes, U. S. Nat. Mus. 52561*a*, 52563*a*.

PLECTOTROPHIA Ulrich and Cooper, n. gen.

Internally like *Huenella*, but externally with fine, distant costellae. Genotype, *Plectotrophia bridgei* Ulrich and Cooper.

PLECTOTROPHIA BRIDGEI Ulrich and Cooper, n. sp.

Similar to *Plectotrophia alata* (Walcott) (*Syntrophia a.*, U. S. Geol. Survey, Mon. 51, p. 799, pl. 103, figs. 3, 3*a–e*, 1912), but is larger and lacks the strong, mucronate cardinal extremities. Upper Cambrian, Wilberns formation, south slope of Point Peak, Llano quadrangle, Texas. Syntypes, U. S. Nat. Mus. 91335*a–i*. Ventral valve 91335*e* is 8.5 mm. long, 12.5 mm. wide, hinge 12.75 mm.; dorsal valve 91335*h* is 8.2 mm. long, 12.8 mm. wide, 12 mm. hinge.

Subfamily MESONOMIINAE Ulrich and Cooper, n. subfam.

Huenellids with a rudimentary cardinal process.

MESONOMIA Ulrich and Cooper, n. gen.

Finely and closely costellate, uniplicate; brachiophore plates recumbent; simple cardinal process. Genotype, *Eoorthis iophon* Walcott (Smithson. Misc. Coll., vol. 67, no. 9, p. 507, pl. 114, figs. 1, 2, 4, 5 (not 3); pl. 119, fig. 14, 1924). Syntypes, U. S. Nat. Mus. 69738, 69739, 69741, 69742, 69793 (not 69740).

GLYPTOTROPHIA Ulrich and Cooper, n. gen.

Externally imbricate, finely and distantly costellate, uniplicate; interior like *Mesonomia*. Genotype, *Glyptotrophia imbricata* Ulrich and Cooper.

GLYPTOTROPHIA IMBRICATA Ulrich and Cooper, n. sp.

This species differs from *G. jasperensis* (C. H. Kindle) (*Huenella j.*, Field Nat., vol. 43, no. 7, p. 146, fig. 10, 1929) in having more closely spaced costellae, shallower ventral sulcus, shorter tongue, and broader, lower fold in the dorsal valve. Mons formation, Douglas Lake Canyon Valley, 12¾ miles E. 5° N. of Lake Louise, Alberta, Canada. Syntypes, U. S. Nat. Mus. 91212*a–d*.

Family TETRALOBULIDAE Ulrich and Cooper, n. fam.

Interior as in *Tetralobula* with subparallel brachiophore plates.

TETRALOBULA Ulrich and Cooper, n. gen.

Syntrophioid, finely costellate; ventral valve with spondylium; dorsal valve with two convergent, discrete brachiophore plates; adductor muscles elevated on lobate swelling. Genotype, *Tetralobula delicatula* Ulrich and Cooper.

TETRALOBULA DELICATULA Ulrich and Cooper, n. sp.

Small, wider than long, narrow-hinged. Ventral valve gently convex; sulcus wide, deep, originating at middle; dorsal fold low; muscular callosities well developed. Syntypes, U. S. Nat. Mus. 91904*a–m*. Syntype (ventral valve) 91904*e*, 7.5 mm. long, 9.5 mm. wide, 6.5 mm. along hinge. Chepultepec formation, 1½ miles northwest of Quicksburg, Woodstock quadrangle, Virginia.

TETRALOBULA IMBRICATA Ulrich and Cooper, n. sp.

Differs from *T. delicatula* by its larger size, coarser costellae and strongly imbricate exterior. About 50 feet above base of Hastings Creek formation, about one-half mile a little south of east of Philipsburg, Quebec. Syntypes, U. S. Nat. Mus. 91105*a–d*. Ventral valve 91105*a*, 8 mm. long, 10 mm. wide; dorsal valve 91105*c*, 10 mm. long, 11.5 mm. wide.

TETRALOBULA QUADRATA Ulrich and Cooper, n. sp.

Largest in size of known species, with fine costellae, 4 to 1 mm.; quadrate in outline. Morgan Corners formation, ⅓ mile east of Philipsburg, Quebec, Canada. Syntypes, U. S. Nat. Mus. 91096*a–f*. Ventral valve 91096*b*, 13 mm. long, 15 mm. wide, hinge 11.5 mm.; dorsal valve 91096*a*, 10.5 mm. long, 13.5 mm. wide.

TETRALOBULA TRANSVERSA Ulrich and Cooper, n. sp.

Differs from *T. quadrata*, with which it occurs, by its transverse form and finer costellae, 6 in 1 mm. at the front. Syntypes, U. S. Nat. Mus. 91098*a–e*. Ventral valve 91098*d*, 10.5 mm. long, 17.5 mm. wide; dorsal valve 91098*b*, 10.5 mm. long, 17 mm. wide, hinge 9? mm.

PUNCTOLIRA Ulrich and Cooper, n. gen.

Internally like *Tetralobula*, but with a cardinal process. Surface marked by radial rows of pits, as in *Porambonites*. Genotype, *Punctolira punctolira* Ulrich and Cooper.

PUNCTOLIRA PUNCTOLIRA Ulrich and Cooper, n. sp.

Small, dorsal umbo sulcate, but anterior marked by high, steep, subangular fold; ventral valve deeply sulcate at front. Syntypes, U. S. Nat. Mus. 91686*a–h*. Syntype (ventral valve) 91686*a*, 6 mm. long, 13 mm. wide; syntype (dorsal valve) 91686*g*, 7.5 mm. long, 10.5 mm. wide. Lower Pogonip, ridge east of Hamburg Ridge, southeast of Hamburg Mine, Eureka District, Nevada.

Family CLARKELLIDAE Schuchert and Cooper, 1931

Clarkella Walcott, 1908; *Syntrophinella* Ulrich and Cooper, 1934; *Syntrophina* Ulrich, 1928.

CLARKELLA MCGERRIGLEI Ulrich and Cooper, n. sp.

Differs from *C. montanensis* Walcott (U. S. Geol. Survey Mon. 51, p. 809, pl. 104, figs. 2, 2*a–d*, 1912) in its deeper ventral sulcus with more angular bounding plications, and the rounded, narrower dorsal fold. Middle Hastings Creek formation, 1 mile east of Philipsburg, Quebec, Canada. Holotype, U. S. Nat. Mus. 91477*a;* paratypes, U. S. Nat. Mus. 91477*b–f*. Holotype, a dorsal valve, 9.5 mm. long, 11.5 mm. wide.

SYNTROPHINA CARINIFERA Ulrich and Cooper, n. sp.

About the size of *S. campbelli* (Walcott), but with a sharply angular fold and long, pointed ventral tongue. Ozark-

ian boulders, Lévis, Quebec, Canada. Syntypes, U. S. Nat. Mus. 91606*a–f*. Ventral valve 91606*b*, 7.5 mm. long, 8.5 mm. wide; dorsal valve 91606*a*, 7.5 mm. long, 10 mm. wide.

SYNTROPHINA GIBBOSA Ulrich and Cooper, n. sp.

One of the largest *Syntrophinas*, with a rotund dorsal valve having an inconspicuous fold; ventral valve flatly convex, with a swollen umbo but shallow sulcus and long rounded tongue. Differs from all known species in its rotund form and outline. Middle of Hastings Creek formation, three-fourths of a mi. a little south of east of Philipsburg, Quebec. Holotype, U. S. Nat. Mus. 91628*e*, 10.5 mm. long, 11 mm. wide. Paratypes U. S. Nat. Mus. 91628*a–d, f*.

SYNTROPHINA MISSOURIENSIS Ulrich and Cooper, n. sp.

Differs from *S. campbelli*, which it strongly resembles, in having a less rounded contour, less inflated valves, deeper sulcus, and a more prominent fold. Top of Gasconade formation, 1½ miles up Spring Creek from Rock Bridge, Missouri. Syntypes U. S. Nat. Mus. 91641*a–g*, 91643*a–h*. Ventral valve 91641*a*, 5 mm. long, 7 mm. wide; dorsal valve 91641*b*, 5.5 mm. long, 8 mm. wide.

DIAPHELASMA Ulrich and Cooper, n. gen.

Like *Syntrophina* but with dorsal lamellae reduced and widely separated. Genotype, *Diaphelasma pennsylvanicum* Ulrich and Cooper.

DIAPHELASMA PENNSYLVANICUM Ulrich and Cooper, n. sp.

Widely elliptical, biconvex, dorsal valve with greater convexity; ventral valve flatly convex; sulcus wide, shallow, originating a little posterior to middle; tongue long, bluntly pointed. Dorsal fold low, narrowly rounded, originating a little anterior to the beak. Syntypes, U. S. Nat. Mus. 91654*a–f*. Syntype (ventral valve) 91654*a*, 8.5 mm. long, 10 mm. wide, hinge 5 mm., thickness 2 mm.; syntype (dorsal valve) 91654*e*, 9 mm. long, 11 mm. wide, 5 mm. thick. Nittany formation, about two-thirds of a mile northwest of Shafferville, Tyrone quad., Pennsylvania.

DIAPHELASMA BREVISEPTATUM Ulrich and Cooper, n. sp.

Differs from *D. pennsylvanicum* in its large size, broadly elliptical outline, with the fold and sulcus nearly obsolete. Basal Luke Hill formation, 1 mile a little south of east of Philipsburg, Quebec, Canada. Syntypes, U. S. Nat. Mus. 91596*a–c*, 91598*a*. Ventral valve 91596*b*, 11 mm. long, 17 mm. wide; dorsal valve 91596*a*, 10.5 mm. long, 16.5 mm. wide.

DIAPHELASMA COMPLANATUM Ulrich and Cooper, n. sp.

This species differs from *D. pennsylvanicum* in its more rounded contours; short fold, extending only to middle of valve; long, broadly rounded tongue, and shallow short sulcus. The fold and sulcus are better developed than in *D. breviseptatum*. Dorsal lamellae greatly abbreviated. Manitou limestone, boulder in Williams Canyon, north of Manitou, Colorado. Holotype, U. S. Nat. Mus. 91618*a*, 10 mm. long, 11.5 mm. wide, 7 mm. thick. Paratypes, U. S. Nat. Mus. 91618*b–d*, 91621*a–e*.

DIAPHELASMA QUEBECENSE Ulrich and Cooper, n. sp.

This species resembles *D. pennsylvanicum* in having the fold extend posterior to the middle, but the fold is more rounded and the ventral sulcus shallower and less angular. About 50 feet above the base of the Hastings Creek formation, one-half mile a little south of east of Philipsburg, Quebec. Syntypes, U. S. Nat. Mus. 91639*a–j*. Ventral valve 91639*a*, 8 mm. long, 10 mm. wide; dorsal valve 91639*g* has the same measurements.

Family SYNTROPHOPSIDAE Ulrich and Cooper, n. fam.

With brachiophores narrowly convergent dorsally.

SYNTROPHOPSIS Ulrich and Cooper, n. gen.

Like *Syntrophina* and *Diaphelasma* externally, but differing in the short, converging brachiophore plates. Genotype, *S. magna* Ulrich and Cooper.

SYNTROPHOPSIS MAGNA Ulrich and Cooper, n. sp.

One of the largest syntrophioids known, with gently convex valves, a broad, shallow ventral sulcus in front of the middle, and a low, broad fold at the front half of the dorsal valve. Holotype, U. S. Nat. Mus. 91137, 17.5 mm. long, 21 mm. wide, 14 mm. thick, hinge 11 mm. Paratype, U. S. Nat. Mus. 91133. Black Rock formation, quarry at Black Rock, Arkansas.

SYNTROPHOPSIS CASSINENSIS Ulrich and Cooper, n. sp.

Differs from *S. magna* in its gentler contours, having scarcely any development of a dorsal fold and only a faint ventral sulcus. Cassin formation, Fort Cassin, Vermont. Syntypes, U. S. Nat. Mus. 91120*a–c*, 91121*a–c*. Ventral valve 91120*a*, 10 mm. long, 12 mm. wide; dorsal valve 91120*b*, 10.5 mm. long, 14 mm. wide.

HESPEROTROPHIA Ulrich and Cooper, n. gen.

Like *Syntrophopsis* internally but with finely costellate exterior. Genotype, *Hesperotrophia obscura* Ulrich and Cooper.

HESPEROTROPHIA OBSCURA Ulrich and Cooper, n. sp.

Small, biconvex; ventral valve with a median sulcus defined at front margin only; dorsal fold scarcely visible; spondylium wide and low; dorsal lamellae long, subparallel. Syntypes, U. S. Nat. Mus. 92882*a–k*. Syntype 92882*a* (ventral valve), 8 mm. long, 11 mm. wide, 3 mm. thick, hinge 6 mm. Sarbach formation, Fossil Mountain, 7.6 miles northeast of Lake Louise, Alberta, Canada.

RHYSOSTROPHIA Ulrich and Cooper, n. gen.

Externally resembling *Cliftonia* (*Oxoplecia*), but internally like *Syntrophopsis*, with a spondylium and narrowly discrete, dorsally convergent lamellae in the dorsal valve. Genotype, *Rhysostrophia nevadensis* Ulrich and Cooper.

RHYSOSTROPHIA NEVADENSIS Ulrich and Cooper, n. sp.

Large for the genus, with a deep ventral sulcus and strong dorsal fold. Four to 7 costae in sulcus, 9 to 11 on flanks. Holotype, U. S. Nat. Mus. 91172, 11 mm. long, 16 mm. wide, 7.5 mm. thick, hinge 4.5 mm. Paratypes, U. S. Nat. Mus. 92884*a–e*. Upper Pogonip, Ikes Canyon, east side Toquima Range, Roberts Mountains quad., Nevada.

RHYSOSTROPHIA OCCIDENTALIS Ulrich and Cooper, n. sp.

Differs from *R. nevadensis* in its finer ornamentation, 16 costellae on flanks of shell and 6 in the sulcus. The fold and sulcus are narrower than in *R. nevadensis*. Upper Pogonip, Ikes Canyon, east side Toquima Range, Roberts Mountains quad., Nevada. Holotype, U. S. Nat. Mus. 91174, 14.5 mm. long, 20 mm. wide, 10 mm. thick, hinge 5 mm.

RHYSOSTROPHIA TRANSVERSA Ulrich and Cooper, n. sp.

Differs from the preceding in its smaller size and transverse form, being twice as wide as long. Stanbridge conglomerate, range 6, lot 20, Stanbridge Township, near Mystic, Quebec. Syntypes, U. S. Nat. Mus. 91175*a–c*. Ventral valve 91175*b*, 5 mm. long, 10.5 mm. wide; dorsal valve 91175*a*, 5.5 mm. long, 12 mm. wide.

Family SYNTROPHIIDAE Schuchert, 1896

Subfamily XENELASMINAE Ulrich and Cooper, n. subfam.

Syntrophiidae with discrete dental plates.

XENELASMA Ulrich and Cooper, n. gen.

Exterior like *Syntrophina*, but the ventral valve possesses discrete dental plates, and the dorsal valve a narrow cruralium like that of *Syntrophia*, s. s. Genotype, *Xenelasma syntrophioides* Ulrich and Cooper.

XENELASMA SYNTROPHIOIDES Ulrich and Cooper, n. sp.

Small, smooth, wider than long, with a gentle ventral sulcus and low dorsal fold defined at the front half of the valves. Gently biconvex. Syntypes, U. S. Nat. Mus. 91684*a–n*. Syntype 91684*j* (ventral valve), 7.5 mm. long, 10 mm. wide, 2 mm. thick; syntype 91684*b* (dorsal valve), 7 mm. long, 10 mm. wide, 2 mm. thick. Longview formation, 4 miles north of Roanoke, Virginia.

Subfamily SYNTROPHIINAE Ulrich and Cooper, n. subfam.

Syntrophiidae with a spondylium. *Syntrophia* Hall and Clarke, 1891.

SYNTROPHIA LONGAEVA Ulrich and Cooper, n. sp.

Differs from *S. lateralis* Hall and Whitfield by its subcircular outline, broad shallow ventral sulcus, longer median septa in both valves. Basal Luke Hill, boulders in Naylor Ledge and Upper Hastings Creek formations, about 1 mile a little south of east of Philipsburg, Quebec. Syntypes, U. S. Nat. Mus. 91677*a–j*; 91675*a*, *b*. Ventral valve 91677*c*, 15 mm. long, 17 mm, wide; dorsal value 91677*d*, 13 mm. long, 14mm. wide.

Family CAMERELLIDAE Hall and Clarke, 1894

Rhynchocamera Schuchert and Cooper, 1932.

IDIOSTROPHIA Ulrich and Cooper, n. gen.

Like *Camerella* internally, but broadly flabellate, and rectimarginate. Interareas obsolete. Genotype, *I. perfecta* Ulrich and Cooper.

IDIOSTROPHIA PERFECTA Ulrich and Cooper, n. sp.

Rather large, subpentagonal in outline, unequally convex, dorsal valve with greatest convexity and depth. Both beaks incurved, the ventral beak overlying the dorsal one. Surface marked by about 16 low costae confined to front half of valve. Holotype, U. S. Nat. Mus. 92885*a*, 14.5 mm. long, 16 mm. wide, 9 mm. thick, hinge 2 mm. Paratypes, U. S. Nat. Mus. 92885*b–d*. Stanbridge conglomerate, range 6, lot 20, near Mystic, Quebec, Canada.

NEOSTROPHIA Ulrich and Cooper, n. gen.

Internally like *Camerella* but with a strong fold and sulcus. Anteriorly costate. Genotype, *Neostrophia subcostata* Ulrich and Cooper.

NEOSTROPHIA SUBCOSTATA Ulrich and Cooper, n. sp.

Subpentagonal, narrow-hinged, narrowly lenticular in profile, strongly uniplicate. Ventral valve with a long, gently geniculated tongue; dorsal valve with a narrow, flat-topped fold. Holotype, U. S. Nat. Mus. 66309*a*, 10 mm. long, 10.5 mm. wide, 5 mm. thick, hinge 2 mm. Paratypes, U. S. Nat. Mus. 66309*b–f*. Stanbridge conglomerate, range 6, lot 20, near Mystic, Quebec, Canada.

JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 7, PP. 632–636, 7 TEXT-FIGS., OCTOBER, 1936

A *TIMANITES* FROM UPPER DEVONIAN BEDS OF AMERICA

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and
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ABSTRACT

An Upper Devonian ammonoid *Timanites occidentalis* is described from Alberta. Previously *Timanites* has been known to occur in only the Timan Mountains of northern Russia, and probably the Polish Mittelgebirge.

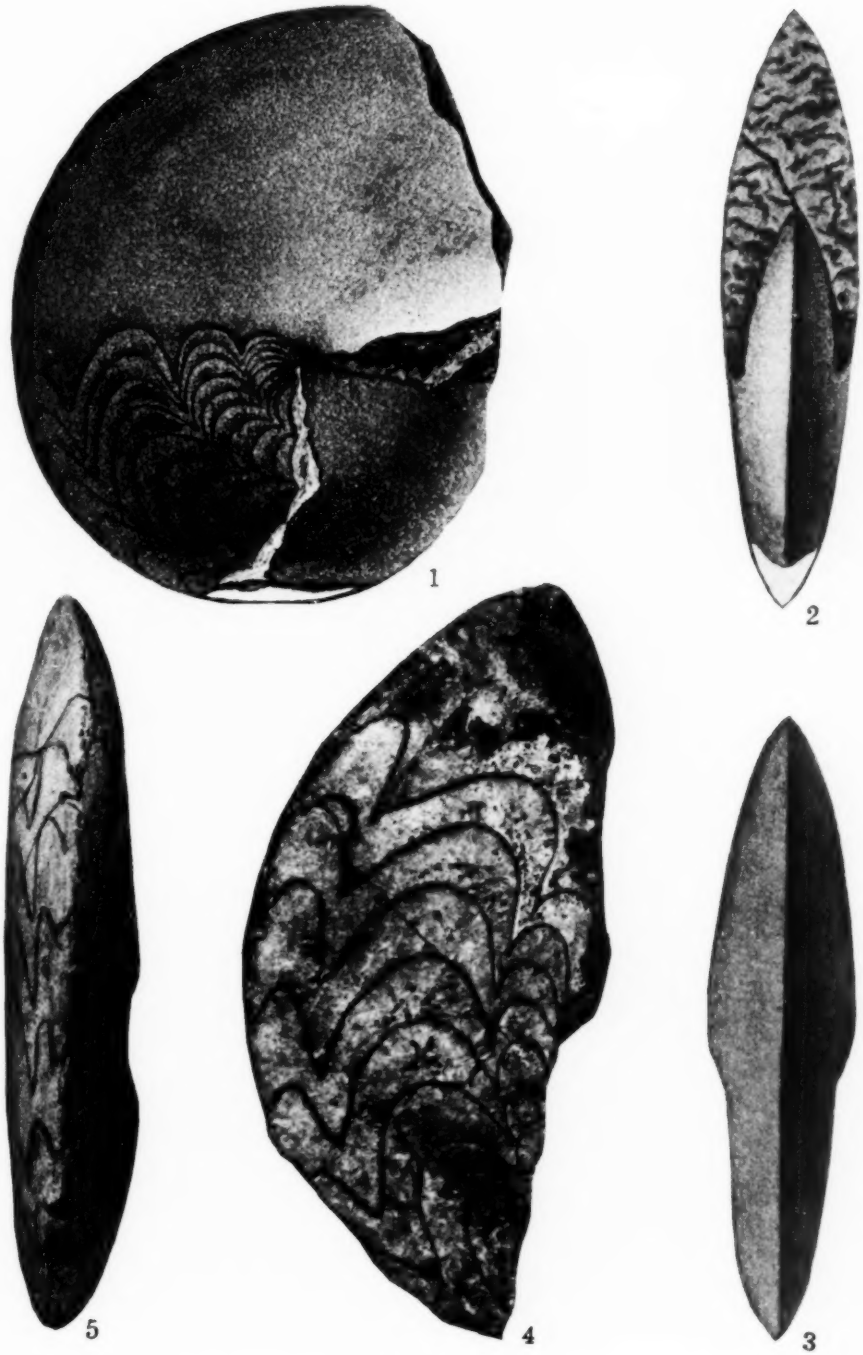
During their recent geological studies in Jasper Park, Alberta, Allan, Warren, and Rutherford (1) obtained a single goniatite from the Minnewanka formation. This specimen was tentatively identified as *Manticoceras* cf. *M. oxy* Clarke, but further study has shown that its affinities are with *Timanites* rather than *Manticoceras*. *Timanites* was established in 1882 by Mojsisovics (7) in his classical work on *Die Cephalopoden der mediterranen Triasprovinz* and was based on a goniatite from the Upper Devonian of the Timan Mountains of northern Russia that Keyserling (5) had described and illustrated in 1846 and had erroneously referred to *Goniatites acutus* Münster. Miller in a manuscript awaiting publication (6) has called attention to the fact that this genotype is without a valid specific name, and has proposed to call it *Timanites keyserlingi*.

In 1899 Holzapfel (4) published his well-known report on *Die Cephalopoden des Domanik im südlichen Timan*, and in it he described and illustrated excellent representatives of the genotype of *Timanites* (Figs. 1–3), and a congeneric form which he named *T. stuckenbergi*. Also, in accordance with a letter that he received from Gürich, Holzapfel included *Höninghausia archiaci* Gürich in the synonymy of the genotype of *Timanites*. Gürich (3) had proposed the name *Höninghausia archiaci* in 1896 for *Goniatites hoeninghausii* D'Archiac and De Verneuil (2) [not *Ammonites hoeninghausi* Von Buch],

EXPLANATION OF FIGS. 1–5

FIGS. *1–3*—*Timanites keyserlingi* Miller, Ms. Three views, all ×1, of a mature specimen from the lower Upper Devonian of the Timan Mountains of northern Russia, included here to show the striking similarity of this form, the genotype of *Timanites*, to *T. occidentalis*. (After Holzapfel.) (p. 635)

4, 5—*Timanites occidentalis* Miller and Warren, n. sp. Lateral and ventral views, ×1, of the holotype, which came from the Minnewanka formation in Jasper Park, Alberta. (p. 634)



FIGS. 1-5

and, at the same time, he had referred to the species a worn, fragmentary specimen from some unknown horizon in the Polish Mittelgebirge. Apparently Holzapfel intended to include in the synonymy of the genotype of *Timanites* only Gürich's Polish specimen, and Gürich's name *H. archiaci*, a valid specific name, should be retained and applied to the form figured by D'Archiac and De Verneuil as *Goniatites hoeninghausii*. The Polish specimen in question probably represents a distinct species of *Timanites* and is without a valid specific name. Insofar as we have been able to ascertain, no other representatives of the genus *Timanites* have been described, and *Goniatites hoeninghausii* D'Archiac and De Verneuil [=*Höninghausia archiaci* Gürich] and *Ammonites multiseptatus* Von Buch, which have been referred to this genus by some authors, should be eliminated from it. The former should be referred to *Höninghausia* and the latter to *Beloceras*.

In the Timan Mountains *Timanites* occurs in association with *Manticoceras*, and its age is clearly lower Upper Devonian, that is, the beds which carry it there are to be correlated in a general way with the so-called *Manticoceras*-Stufe or Oberdevonstufe I of Germany—Wedekind (9) states that they are equivalent to Oberdevonstufe Iα. In eastern North America the genus *Manticoceras*, which characterizes Oberdevonstufe I, ranges throughout the Senecan and up into the lower portion of the Chautauquan (Tully? to Canadaway, inclusive), but the *Timanites*-bearing beds of northern Russia are probably not greatly different in age from the Naples formation of New York, and presumably the portion of the Minnewanka formation which yielded the specimen we are studying is of approximately the same age. This last conclusion was reached also by Allan, Warren, and Rutherford (1).

Since *Timanites* has previously not been known to occur outside of Russia and Poland, the discovery of a typical representative of it in Alberta seems to us to be more than ordinarily interesting and to be worth recording. Furthermore, the presence of this genus in the upper part of the lower Minnewanka can be said to confirm indirectly the correlation of part of that formation with the Naples formation of New York. In view of the fact that the form we are studying is the first representative of the genus *Timanites* to be found in the Western Hemisphere, we propose to name it accordingly.

TIMANITES OCCIDENTALIS Miller and Warren, n. sp.
Figures 4–6

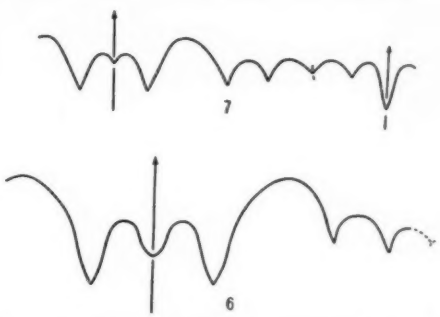
Conch sublenticular, ammoniticonic, moderately large, attaining a maximum diameter (measured across the umbilicus) of at least 105 mm. and a maximum height and width of conch of at least 57 mm. and 20 mm., respectively. Whorls compressed, subsagittate in cross section, angular ventrally, very broadly rounded (almost flat) laterally, and rather deeply impressed dorsally. Umbilicus apparently closed, small, inconspicuous. Each external suture forms a very large unequally trifid ventral lobe; on either

side of it a smaller, but nevertheless rather large, asymmetrical, more or less U-shaped first lateral saddle; a much smaller, shorter, asymmetrical, V-shaped first lateral lobe; a somewhat larger, more or less U-shaped, asymmetrical second lateral saddle; a V-shaped second lateral lobe; and a saddle which apparently is rounded and probably extends to the center of the closed umbilicus. The outer two of the three prongs of the ventral lobe are longer than the median one, and all are more or less V-shaped. Siphuncle ventral and marginal in position.

Remarks.—The above description is based on a single internal mold that represents the adoral two-fifths of the outer volution of the phragmocone and a small part of the living chamber. This specimen is only moderately well preserved and retains no trace of the surface markings of the test. We have not been able to ascertain the nature of the internal sutures or even the depth of the impressed zone, and the umbilical portions of the external sutures seem to have been distorted during fossilization.

The presence of two lateral lobes in the external sutures of this form indicates clearly that it belongs in the genus *Timanites* rather than in *Ponticeras, Manticoceras, Koenenites,* or *Höninghausia,* in all of which there is only one lateral lobe outside the umbilical shoulder. *Timanites occidentalis* differs from *T. stuckenbergi* in that its conch is angular rather than rounded ventrally and its umbilicus apparently closed rather than open. *T. keyserlingi* Miller Ms. (Figs. 1–3), seems to resemble *T. occidentalis* very closely, and we are not able to point out any very satisfactory means of distinguishing these two forms. Still, since the only known representatives of them came from such widely separated localities, it seems more probable that they represent two distinct species rather than that all are conspecific, and well preserved representatives of the two could probably be differentiated readily. So little detailed information is available in regard to the unnamed representative of *Timanites* which Gürich (3) described from the Polish Mittelgebirge that adequate comparisons are not possible.

Occurrence.—Upper part of lower Minnewanka formation [that is, in a limestone member of that formation, the so-called Flume limestone of Raymond (8), immediately underlying the Blackface Mountain or Perdrix shale], on northeast shoulder of Roche Miette in Jasper Park, Alberta, where it is associated with the *Spirifer jasperensis* fauna (1). The age of the containing beds is regarded as Upper Devonian.



FIGS. *6, 7*—Diagrammatic representations of mature sutures of *Timanites occidentalis* Miller and Warren, n. sp., and *Timanites keyserlingi* Miller, both ×¾. Fig. *7* is adapted from Holzapfel. The umbilical portions of the specimen on which fig. *6* is based appear to have been somewhat distorted during fossilization.

Repository.—Univ. Alberta Geol. Mus., Dv. 684.

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JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 7, PP. 637–643, 6 TEXT-FIGS., OCTOBER, 1936

EVIDENCES OF INSECT ACTIVITY PRESERVED IN FOSSIL WOOD

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ABSTRACT

Certain Tertiary fossil woods show evidences of attack by coleopterous larvae and others of attack by ants.

There have recently come into my hands three very interesting examples of the work of extinct insects in which burrows or excavations of wood-inhabiting species have been preserved by the subsequent fossilization of the wood. Similar instances must have been observed by others, but I have been able to find scarcely any published references, and one of these unfortunately proved to be a myth. Many years ago Kolbe ('88) described some supposed insect borings in fossil wood which he thought represented the work of a weevil (*Curculionites senonicus*) in a cycad (*Zamiophyllum*). This specimen of "wood" has been shown very recently by Quenstedt ('32) to be of animal origin as it appears to be a portion of a cuttle-fish, probably *Doratoteuthis syriaca!*

At least one case of the fossilization of artifacts constructed by insects has been published. Several fossilized nests of the solitary wasp have been described and illustrated by Handlirsch ('10). These came from the Upper Oligocene of Flörsheim in Europe and resemble very closely the nests made by living potter-wasps of the genus *Eumenes*. The name *Eumenes römeri* has been given to the as yet unknown maker of these nests. The specimens illustrated by Handlirsch are beautifully preserved even to the exit holes of the wasps and there can not be the slightest question of their proper identification; nevertheless they had previously been classified as possible sponges.

Very recently Abel ('33; '34) has described and figured a fossil termite nest from the lower Pliocene of Guntramsdorf, near Vienna. This includes burrows in the wood of a species of *Araucarioxylon* connected with superficial carton-covered galleries similar to those made by a recent species of *Calotermes* that occurs in the Mediterranean region.

No doubt an examination of paleontological collections, particularly those containing specimens of wood and leaves would disclose many examples of insect work or artifacts. Certain galls on the leaves of Tertiary plants have already been described.

BURROWS OF COLEOPTEROUS LARVAE IN FOSSIL WOOD

Some months ago Dr. H. C. Bumpus showed me a piece of fossil

wood which contains numerous burrows, evidently excavated by some animal before the wood had become fossilized. This was found, together with another similar piece, by Ranger Ben Arnold on the north slope of Jasper Creek, Yellowstone National Park. Prof. I. W. Bailey has very kindly examined the wood and tells me that it is a species of soft pine, practically identical with the present-day Western White Pine, *Pinus monticola*. The age of this specimen is somewhat doubtful, as several floras are represented among the deposits of fossil leaves and wood that occur near the vicinity of Specimen Ridge in this part of Yellowstone Park. The probability is that it is Upper Miocene, since several species of pines have been described by Knowlton ('99) from cones and leaves from the more recent of these floras, and no pines are known from the older Tertiary deposits within this area.

The specimen is a fragment about three inches in diameter and had evidently been exposed to the weather for some time before it was found, as the surface was somewhat stained and supported a scattered covering of lichens. Boiling in a solution of caustic potash removed this as well as some loose soil which partially filled the cavities on its surface. It then presented the appearance shown in Fig. 1. It was then evident that the cavities extended for only a short distance into the wood, being in many cases only shallow pits which vary in depth from a mere concavity to some 5 or 10 mm. Only two or three could be seen actually to extend through the specimen when held up to the light. The cavities are all practically round in cross-section except where adjacent ones coalesce. The bottom of each is uniformly concave and shows under a lens or low power of the miscroscope a very characteristic sculpture, deep, minute striations, sometimes quite irregular, but most frequently more or less evidently transverse or occasionally somewhat radially arranged. It thus appeared as though only the ends of burrows were preserved on both sides of the specimen, presumably having entered it from the wood which had originally been adjacent to each side. The broad edge of the specimen showed, however, indications of irregular weathered burrows extending from one side to the other, so I had the specimen sawed into slabs (across the grain) to determine, if possible, what trace of burrows might show on the sawn surfaces.

After sawing, the cut surface presented the appearance shown in Fig. 2. There can be seen numerous tunnels, nearly all circular in outline, indicating a longitudinal extension of the burrows with the grain of the wood. On the unpolished surface these are much lighter in color and appear as paler circles in the photograph. All are completely filled with a crystalline material that shows a very distinctly radial arrangement of the crystals surrounding the periphery of the burrow and a more granular central core. This filling varies in color, but is stained with brown, and from its appearance

under the microscope I suspected that it might be calcite. A piece was immersed in dilute hydrochloric acid and the presence of calcite was at once verified by the rapid evolution of gas and the subsequent disappearance of the filling after the acid had acted on the material overnight. After watching the initial rapid disintegration of the calcite crystals, I was much surprised to find that the clearing out of the burrows had not progressed beyond a certain point and that at the depth of a few millimeters there was in each case a concave, siliceous end to each burrow, showing the same finely striated surface structure that had been previously noted on the weathered outer surface of the specimen.

From this evidence it seems that the burrows in the wood were originally filled only in part with frass or borings and that there were open spaces devoid of frass. During fossilization these tubular cavities were first filled with calcite crystals. Later the slower process of silicification occurred and the tightly packed borings were silicified as well as the wood, thus imbedding the rods of calcite in the siliceous matrix. All well-preserved fossil wood from this region has been silicified by immersion in water issuing from thermal springs. Such water contains also varying amounts of calcium carbonate, which is rapidly deposited, since its solution depends upon the presence of carbon dioxide and the latter passes off quite completely from the warm or hot water once the excessive subterranean pressure is relieved. That the calcite was deposited first in this specimen is evident also from the presence of a thin layer of opaline silica that fills a crack in the wood and extends directly across two of the circular burrows. Unless the cavity had already been filled with calcite the opal would have necessarily invaded the entire cavity as is the case generally in the cavities of fossil wood which supply the opal of commerce. Some calcite is present, however, in the fossilized frass, as continued treatment with dilute hydrochloric acid with the addition of heat and boiling results in the further evolution of gas, a deepening of the tubular spaces, and the appearance of minute insoluble particles. These latter appear under the microscope to be silicified remains of the frass loosened by the removal of the calcite matrix. Among this detritus there are also what appear to be bits of very well preserved fungus hyphae. At high magnification these are seen to be branched and coalescent into a net-work. They represent unquestionably the fungi which invaded the frass while it was in a fresh moist condition.

There seems to be no doubt that the borings were made by insects, but it is not so easy to determine what kind of insect is responsible. The generally quite uniform size of the burrows and the very considerable number suggest a powder-post beetle of some sort. The injury to wood caused by beetles of the family Lyctidae is closely similar, but the work of these beetles is confined to the sapwood, since, as has recently been shown by

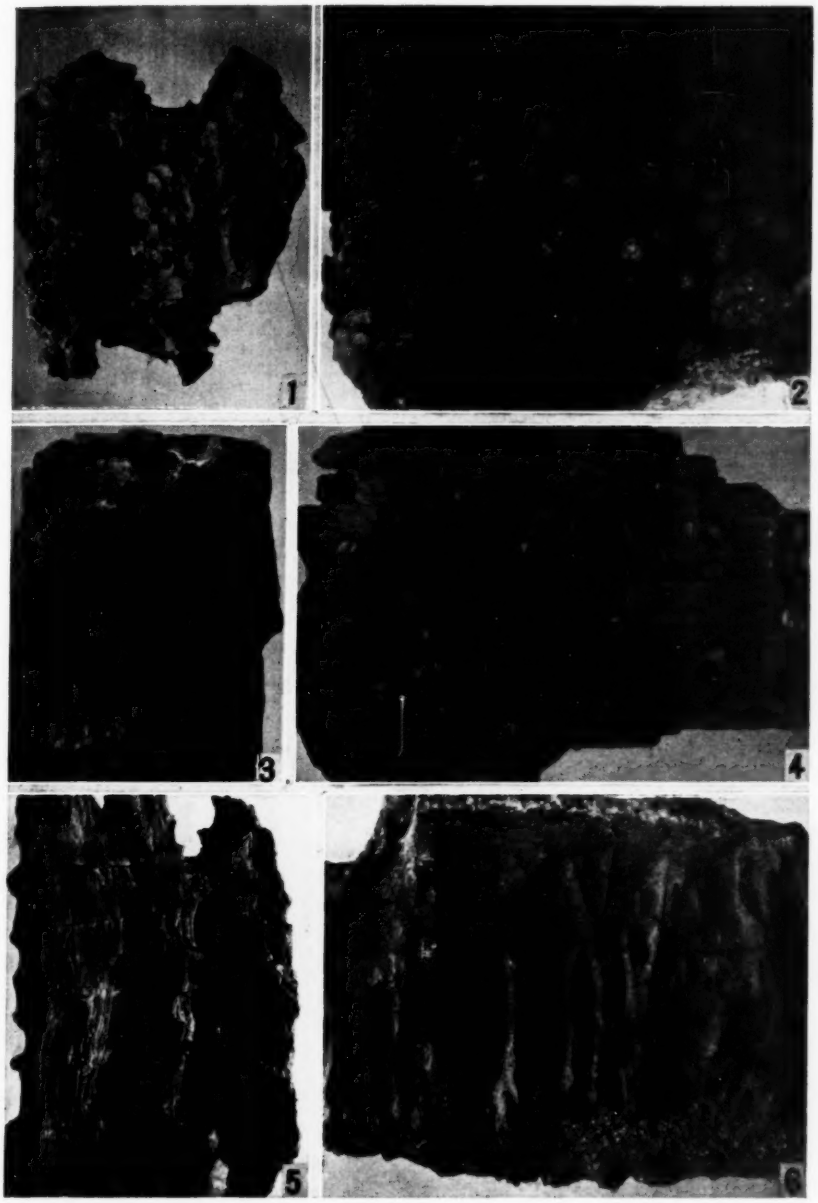
Wilson ('32; '33), the larvae depend for food upon starches present in considerable quantities in sapwood but not in the heartwood. Moreover, they are practically restricted to the timber of hardwood (deciduous) trees.

Other related beetles of the families Ptinidae, Anobiidae, and Bostrychidae excavate similar burrows in dry wood, commonly entering the heartwood and some of them attacking coniferous woods. The burrows in the fossil wood appear to agree most closely with those of these beetles, and are most probably the work of a species of Bostrychidae. Snyder ('27) has published some photographs of wood damaged by *Xylobiops basilare* which resemble closely the photographs published herewith of the fossil wood, and St. George ('29) gives another very good photograph of the work of this species. Furthermore, the Bostrychidae commonly attack freshly felled logs in moist temperate climates, while the Lyctidae, and generally the Ptinidae also, attack only well seasoned wood, except in very hot, dry regions where wood seasons rapidly under natural conditions out of doors. There is one difference, however, which I am unable to reconcile with the work of powder-post beetles in general. That is the restriction of the frass or powder to parts of the burrow, whereby short spaces were apparently left open in the burrows by the crowding of the frass into the remaining portions. There is, of course, the possibility that the burrows in the fossilized wood might be the work of some other type of beetle or even of a wood-wasp, perhaps of the family Xiphidryiidae or Siricidae. I do not believe, however, after comparisons with the work of these other wood-boring types, that such could be the case.

A second specimen of fossil borings (Figs. 3, 4) is contained in a piece of silicified wood from the Paris Basin, France, of Miocene age, now in the collection of the Harvard University Museum. This was shown to me by Mr. T. S. Darrah, who had been so good as to make sections of the other pieces of wood mentioned in this paper. This is a small piece of hardwood, apparently oak, perforated by numerous burrows, nearly all of which extend in a horizontal plane, *i.e.*, against the grain, following the curvature of the annual growth rings. These burrows are circular or practically so and vary in diameter from 1 to nearly 3 mm. They are probably made by some Lymexylonid timber beetle, or possibly a tenebrionid like *Strongylium*, as they are closely similar to the work of the living timber beetles of this type.

ANT GALLERIES IN FOSSIL WOOD

In the eastern part of San Juan County, New Mexico, along the highway which leads from Aztec to Cuba, about 50 miles south of the former town, there are scattered deposits of fossil wood. This is exposed in gullies that extend down the sides of some of the low hills which rise along the eastern side of the highway. Many large detached pieces and some



FIGS. *1, 2*—Fossil wood (*Pinus* sp.) with beetle borings, about two-thirds natural size; cut through the specimen, showing burrows in cross section, about one and one-half times natural size.

3, 4—Fossil wood (*Quercus* sp.) with beetle borings, showing the longitudinal extension of the burrows; side view of specimen, showing burrows in cross-section; about natural size.

5, 6—Excavations in fossil wood made by ants (*Camponotus?*); another fragment from the same log with excavations and also shallower, weathered depressions; about half natural size.

more less intact logs are to be observed and one of the latter was noticed by my daughter to contain some rather regular cavities which she surmised might be excavations made by ants. This log was not very well preserved, as it had evidently been partly rotted before silicification and was more or less broken where it jutted out from the surface soil of the hill slope. We secured several pieces with well defined cavities and a later examination seems to show that the original log harbored a colony of ants. In one of the pieces figured (Fig. 5) the ant galleries are very clear-cut, but in another (Fig. 6) there are also numerous much smaller, shallow cavities, undoubtedly of different origin. Before silicification parts of the log had evidently reached the "red-rotten" stage of decay, developing the transverse cracks characteristic of wood in this condition, and these are filled with thin layers of more resistant silica. Between these, later weathering has produced smaller, superficial depressions. The depth, size, and relation of the larger cavities to the siliceous laminae are such, however, that one could not possibly attribute these to cracking and weathering. This, taken together with the close similarity to the burrows of living species of *Camponotus*, makes it quite certain that the fossil wood was excavated by ants. It may be unwise to speculate further as to the probably taxonomic relations of the ants concerned, but as can be seen from the accompanying photographs, the cavities are closely similar to those made by living species of "carpenter ants" of the genus *Camponotus* which are now abundant in many parts of North America. These ants inhabit dry wood, excavating large intercommunicating cavities which generally extend in a slightly sloping horizontal direction, irregularly one above another. These flat cavities are separated by layers of wood that remain intact in places with occasional more or less pillar-like pieces connecting the horizontal partitions. All of the remaining wood is smoothed off, rounded, freed from corners and the cavities completely cleared of debris by the worker ants. The cavities in the fossil wood are somewhat smaller than those made by the common North America *Camponotus herculeanus* and from the number of cavities the colony was probably not so populous as is common with this species.

The fossil wood comes from either the Torrejon or Puerco formation and is of Paleocene age (Reeside, '24). So far no ants have been found in deposits of earlier age than middle Eocene, at which time the family had a very modern aspect, indicating, as in the case of other groups of specialized insects, that they were well differentiated at a much earlier date. The genus *Camponotus* is represented by several species in the Miocene of Florissant, Colorado (Carpenter, '30), and one species is known from the Oligocene of the Baltic amber (Wheeler, '14). Consequently, it is not surprising to find in the Paleocene evidence of species with habits similar to the modern wood-inhabiting forms.

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JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 7, PP. 644–647, 1 TEXT-FIG., OCTOBER, 1936

A NEW RUMINANT FROM THE HEMPHILL MIDDLE PLIOCENE OF TEXAS

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ABSTRACT

Pediomeryx hemphillensis Stirton, n. gen. and sp., based on incomplete mandibles, several upper teeth, and foot and limb bones, of uncertain relationships.

The identification and classification of North American Tertiary ruminants is one of the most difficult problems for students of Late Tertiary mammals. Types, for the most part, are isolated lower jaws or horn cores, and until they have been found associated as parts of one individual or of a group of individuals from one quarry it is impossible to allocate either jaws or horn cores alone to any given genus or species. Nevertheless, because of their rarity, it is important to place all specimens of ruminants on record.

The purpose of this paper is to describe a new genus and species from the Hemphill middle Pliocene (Ogallala formation) of Texas. The material available consists of isolated specimens associated in one quarry.

PEDIOMERYX Stirton, n. gen.

Etymology: πεδίον, a plain; μήρυξ, ruminant, i.e. a plains ruminant.

Genotype: *Pediomeryx hemphillensis* Stirton.

The characters of the genus are those of the type species, described below.

PEDIOMERYX HEMPHILLENSIS Stirton, n. sp.

Text-figure 1

Types: Holotype, right mandible with P_3–M_3 moderately worn, ascending ramus and anterior part of jaw missing; Univ. California Mus. Paleont. 30703. Paratypes, left mandible, P_4–M_3 heavily worn, other teeth and ascending ramus wanting, U.C.M.P. 30289; anterior part of right mandible, P_3–M_1 moderately worn, U.C.M.P. 30704; fragment of right mandible with well worn M_3, U.C.M.P. 30273; one P_3, one P_4, two M_1, one ?M_3, two M_3, five P^4, one P^3, two M^1, one M^2, one M^3, U.C.M.P. 30706; calcaneum, U.C.M.P. 30707; two astragali, U.C.M.P. 30708–09; metacarpal, U.C.M.P. 30705.

Type locality: Coffee Ranch quarry, 9.3 miles N.E. of Miami, Hemphill County, Texas; Block A2, Sec. 59 of Houston Great Northern R.R. Survey. Locality 20 of Reed and Longnecker (Univ. Texas, Bull. 3231, 1932). Ogallala Formation.

Age: Middle Pliocene.

Diagnosis: Horizontal ramus nearly straight; antero-outer basal ridge on P_4; talonid of M_3 with single outer crescentic cusp, no loop present forming fossettid; no "palaeomeryx folds"; entoconids and hypoconids of P_3–$_4$ not isolated; anterior fossettids on lower molars not open lin-

gually; fossettes on upper molars and fossettids on lower molars become isolated in early stages of wear; no heavy cingula on upper molars; P^4 two-rooted; dental formula $I\frac{?}{?}$ $C\frac{?}{?}$ $P^{1\cdot2\cdot3\cdot4}_{2\cdot3\cdot4}$ $M^{1\cdot2\cdot3}_{1\ 2\cdot3}$; brachyselenodont dentition.

Mandible: Horizontal ramus of holotype cracked and but little distorted; diastema between P_3 and C very long, ramus very thin in that region; ramus not deep below molars (about 30 mm. below M_3). Second premolar (P_3) double-rooted; three grooves on lingual side of crown; one groove on labial side, opposite median groove of lingual side; paraconid-metaconid not separate; four ridges on lingual side of tooth, anterior ridge slightly recurved, second is widest, third is longest, and the last only faintly indicated on posterior edge of tooth. Third premolar (P_3) with paraconid and metaconid separate; metaconid and metastylid nearly united in genotype but distinctly separate in other specimens; groove between entoconid and hypoconulid open at base; labial groove deep; hypoconid ridge strong; indication of antero-external cingulum. Fourth premolar (P_4) larger than P_3; metaconid and metastylid united as one cusp; anterior fossettid isolated; entoconid larger; paraconid distinct; deep lingual groove between entoconid and metaconid-metastylid; groove between entoconid and hypoconulid open at base; labial groove deeper than on P_3; antero-external cingulum well defined. First molar (M_1) with no prominent lingual styles or cusps, except paraconid; anterior and posterior cingulum development on labial side; outer pillar attached to hyposelenid; outer and inner crescents opposite; anterior fossettid does not open lingually, no "palaeomeryx fold." Second molar (M_2) like M_1 but larger. Third molar (M_3) with no cusp opposite hypoconulid; hypoconulid crescentic in early stages of wear; pillar between hypoconid and hypoconulid attached to hypoconulid, variable in size; anterior fossettid opens

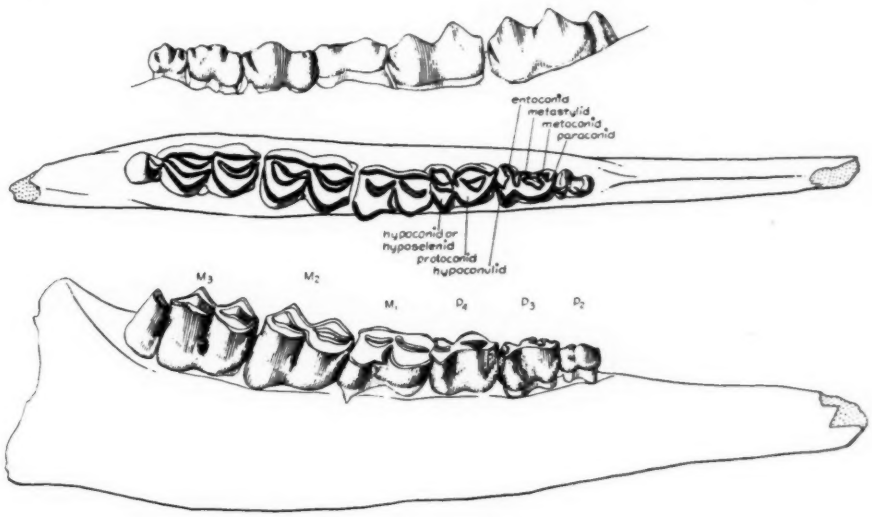

FIG. 1—*Pediomeryx hemphillensis* Stirton, n. gen. and sp., holotype, showing lingual, occlusal and labial views of right mandible, ×3/5. The tritubercular system of dental nomenclature is used in this paper for its convenience in describing teeth and not to indicate cusp homologies with other orders of Mammalia.

lingually near paraconid in early stages of wear (not medially as in Cervidae); posterior fossettid opens labially and posteriorly in early stages of wear.

Upper teeth: First premolar (P^1) two-rooted, anterior root conical, posterior root wide; median and posterior labial cusps present; prominent fossette with tiny interspersed ridges, two labial ridges. Second premolar (P^2) with one lingual and two labial conical roots; larger than P^1 but similar in structure. Third premolar (P^3) three-rooted; fossette opens posteriorly in early stages of wear; elongate laterally; antero-inner basal cingulum; two styles and one rib. First molar (M^1) with three roots; three labial styles and prominent anterior rib; fossettes connected, open to outside in earliest stages of wear; V-fold formed where anterior and posterior crescents unite (this is caused by their failure to unite at their tips); width greater across anterior crescents; inner pillar united to hyposelene; antero-lingual cingulum present. Second and third molars (M^2, M^3) like M^1 but larger.

Milk teeth: Second lower milk tooth (DP_2?) long; paraconid and metaconid separate; metaconid and metastylid widely separate; metastylid smaller than entoconid; groove between entoconid and hypoconulid long, reaches a point at the base of the protoconid opposite entoconid-metastylid groove. Fourth lower milk tooth (DP_4) with three pairs of crescents; anterior and posterior labial cingulum; labial pillars between crescents; fossettids isolated; slight indication of ribs on inner crescents, no stylids.

Limb and foot bones: Metacarpal smaller than in *Dromomeryx borealis* (Cope), relatively shorter and wider than in *Odocoileus;* no prominent anterior groove with foramen near distal end of shaft; distal keels carry over on shaft. A calcaneum and astragalus differ in details from those of *Odocoileus* and *Dromomeryx* (Douglass, 1909).

Comparison with other genera.—The systematic position of *Pediomeryx* is uncertain. It is similar to members of the Cervidae, Palaeomerycidae, Giraffidae and Protoceratidae in having low crowned teeth with pillars between the crescents, but is distinct from members of these families in the detailed construction of the mandibular ramus and teeth. Genera likely to be confused with the new genus differ from it as follows:

Dromomeryx shows less reduction of premolars; no anterior labial cingulum on P_4; curved mandibular ramus; cusp opposite hypoconulid of M_3; no "palaeomeryx fold." (The "palaeomeryx fold" is located on the postero-labial corner of the protoconid of lower molars. It disappears in early stages of wear.)

Dyseomeryx shows the characters of *Dromomeryx* and in addition a long low-crowned P_3; metaconid and metastylid not united on P_4; mesostylid on molars well defined.

Palaeotragus, as figured by Schlosser (1903) and Bohlin (1926), shows P_3 larger and with heavier posterior crest; P_3 and P_4 larger, entoconid and hypoconid isolated as pillars, groove opening externally between protoconid and hypoconid on P_3; anterior fossettid of P_4 opening lingually; fossettids on M_{1-3} remaining open longer; third lobe of M_3 with low cusp opposite hypoconulid. *Palaeotragus* agrees with *Pediomeryx* in possessing a straight ramus and no "palaeomeryx fold."

Palaeomeryx shows heavy cingula on upper molars; other parts are not available for comparison.

Cranioceras cannot be brought into comparison until it is better known. The lower jaws referred to this genus by Matthew (1918, p. 225) are not referable to *Pediomeryx*. The type of *Cranioceras* is a horn core.

Drepanomeryx is based on a horn core (Sinclair, 1915, p. 90). The lower jaw referred to *?Drepanomeryx ?falciformis* by Cook (1922, p. 14) is possibly referable to *Pediomeryx* but it is too deeply worn for accurate comparison. Furthermore, if the genotype of *Drepanomeryx* came

from the lower Snake Creek, as indicated by Matthew (1924, p. 26), the lower jaw and dentition should be much more primitive than in *Pediomeryx*. A typical *Drepanomeryx* lower jaw and dentition may be represented in Matthew's "*Cervavus sinclairi*" (1918, p. 218). In this specimen P_1 is present and the premolars more primitive and elongate than in *Pediomeryx*. Another specimen that is tentatively referred to *Pediomeryx* is part of a lower jaw with P_4–M_3 in place. This specimen was recorded from the Wray fauna of Colorado as "Cervid, Gen. and sp. indet." by Cook (1922, p. 13).

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JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 7, PP. 648–651, 2 TEXT-FIGS., OCTOBER, 1936

THE ILIO-SACRAL ATTACHMENT OF *ERYOPS*

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ABSTRACT

From the pattern of the ligament scars on the sacral rib and ilium of *Eryops* inference is drawn that the main strength of the ilio-sacral attachment of *Eryops* was in the ligaments, a condition structurally intermediate between that of the most primitive amphibians and the the early reptiles.

The ilio-sacral attachment of tetrapods is accomplished by ligaments, cartilage, or actual fusion of the sacral ribs and the blade of the ilium. Bony and cartilaginous attachments are characteristic of terrestrial animals that use their limbs as the primary means of locomotion and of various modifications of these types that have retained the active use of their limbs. Ligamentous attachments appear to have been present in the most primitive tetrapods (1). They also occur in many aquatic descendants of the tetrapod stock, and in terrestrial forms having vestigial limbs either as a result of degeneration or specialization.

Eryops, like the great majority of amphibians, has a single sacral rib. This rib, described in some detail by Case (2), has a broad head with a large capitulum and tuberculum, a short broad neck, and an expanded, spatulate shaft. The expanded distal portion of the rib fits nicely into a depression on the inner surface of the iliac shaft, but in no case is there anything more than a slight pitting of either bone to suggest that there was a cartilaginous attachment between them.

The sacral rib of an undescribed specimen of *Eryops* (Univ. Chicago 1542) and an ilium which is not associated with any other skeletal parts (Univ. Chicago 460) throw new light on the little understood problem of the sacral articulation of the primitive Paleozoic tetrapods.

On the sacral rib of specimen 1542, a series of rugose ridges appear to be scars of attachment of ligaments connecting the rib to the ilium (Fig. 1). A very strong rugose ridge passes from the outer surface of the capitulum diagonally across the head to the dorso-posterior margin of the spatulate shaft. The posterior termination of this ridge is on a process which corresponds in position to the uncinate processes of the anterior dorsolumbar ribs. This suggests that in some ancestor of *Eryops* uncinate processes were present on all the presacral ribs, and that they were lost on the posterior ones as these ribs became shorter. Originating near the mid-point of the strong ridge described above, another crest runs

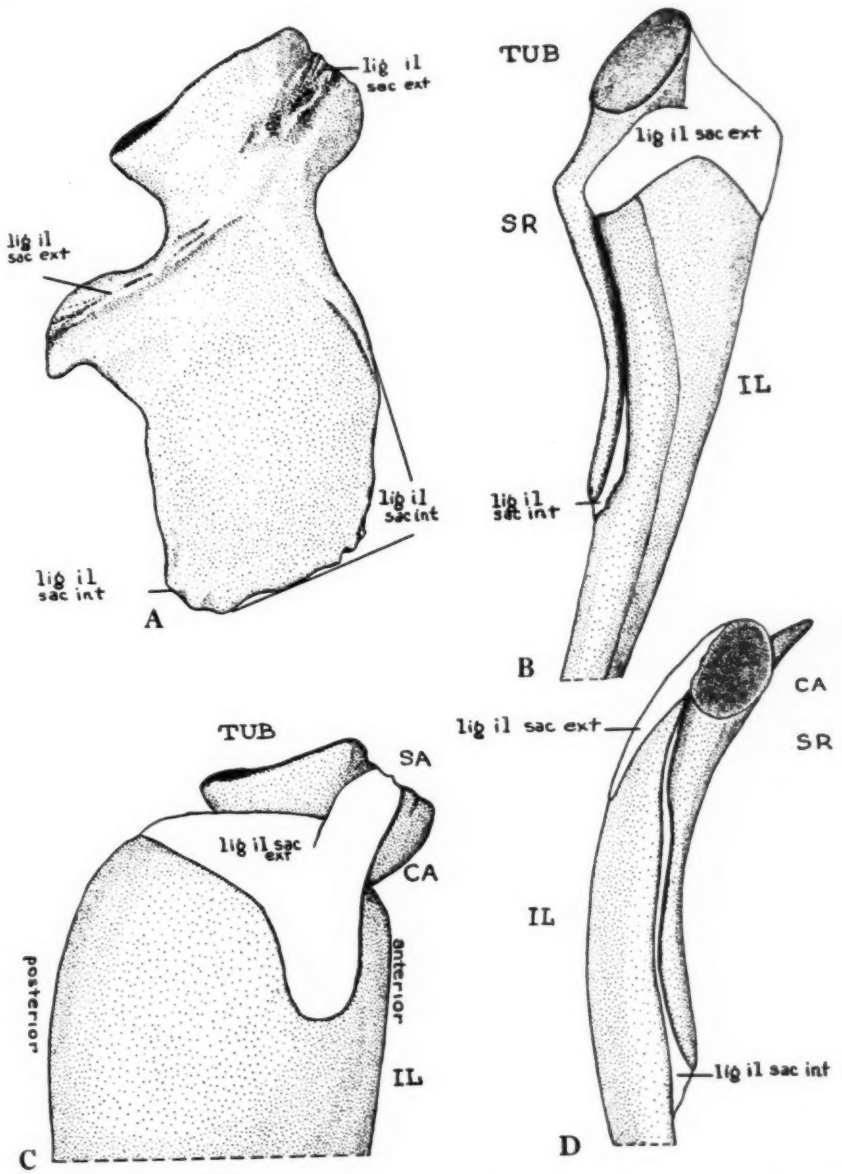

FIG. *1*—The ilio-sacral articulation of *Eryops*. *A*, Sacral rib, external view. *B–D*, Sacral rib and ilium with inferred ligaments; *B*, posterior view; *C*, external view; *D*, anterior view. *CA*, capitulum; *IL*, ilium; *lig. il. sac. ext.*, external ilio-sacral ligaments; *lig. il. sac. int.*, internal ilio-sacral ligaments; *SR*, sacral rib; *TUB*, tuberculum.

approximately at right angles to the first along the anterior margin of the shaft. The ventro-posterior tip of the shaft is terminated by an elliptical, cup-like depression.

Corresponding in position to the markings on the sacral rib, are rugose and ribbed areas on the ilium surface of the ilium to the sacral rib. These ligaments may be termed the external ilio-sacral ligaments (Fig. 1*B–D*). Ridges on the inner surface of the ilium correspond in position to the anterior and posterior margins of the shaft of the sacral rib. Opposite the cup shaped termination of the

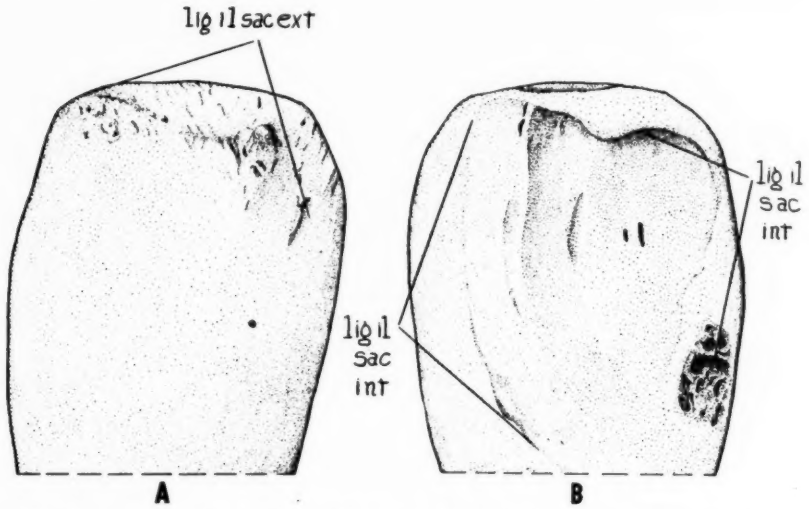

FIG. 2—The ilium of *Eryops; A*, external view; *B*, internal view. For abbreviations see Fig. 1.

(Fig. 2). The slightly shelved crest of the outer surface of the ilium is rugose and is terminated anteriorly by a very strong process. This series of scars corresponds in position and degree of development to the strong ridge on the capitulum and dorsal margin of the sacral rib. The direction of the small rugosities on this part of the ilium indicates that the stress was medial and not anterior or posterior as would be the case had the processes been connected with the axial muscles. Presumably these scars represent areas of attachment of strong ligaments from the outer ventral tip of the rib, there is a deep pitted hollow in the ilium. Strong ligaments appear to have passed from the ilium to the sacral rib in these positions. They may be termed the internal ilio-sacral ligaments (Fig. 1*B–D*).

It seems clear from the above data that the major strength of the ilio-sacral articulation of *Eryops* was derived from the ilio-sacral ligaments, but that cartilaginous support at the contact of the ilium and the sacral rib was incipient. This condition represents a stage decidedly in advance of that described by Watson

(1) in the primitive embolomerous amphibian *Eogyrinus*. However, the development is not as high as that found in *Cacops* (3), a rachitomous form in which there were two sacral ribs with a strong, apparently cartilaginous attachment to the ilium. Comparison with the condition in the Anura and Urodela is valueless because of the high degree of specialization in the former and the degeneration in the latter. The articulation is less advanced than that found in *Seymouria*, an exceedingly primitive reptile.

The condition of the sacrum in *Eryops* appears to represent a stage intermediate, structurally but not phylogenetically, between the most primitive embolomerous amphibians in which ligaments formed the only ilio-sacral support and the more advanced tetrapods in which cartilage formed the main support.

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JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 7, PP. 652–655, 11 TEXT-FIGS., OCTOBER, 1936

THE SYSTEMATIC POSITION OF *TRACHODON*

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ABSTRACT

Trachodon Leidy is shown by the form of the dentary teeth to belong with the hooded duck-billed dinosaurs, Lambeosaurinae, rather than with the flat-headed forms, Hadrosaurinae.

The genus *Trachodon* was described by Leidy in 1856 (1). The genotype, *T. mirabilis*, was based on teeth and tooth fragments from the Judith River formation of Montana, more fully described and figured by Leidy in 1859 (2). In 1858 Leidy described from the "Greensand" of New Jersey a number of splendidly preserved teeth and parts of the skeleton as *Hadrosaurus foulkii* (3). These he more fully described and figured in *Cretaceous reptiles of the United States* in 1865.

There has been considerable confusion as to the systematic position of these two forms and some writers have referred them to a single genus.

In Leidy's types of *Trachodon mirabilis* were included a single-rooted tooth, which we now know belonged to a duck-billed dinosaur, and a double-rooted tooth, which we now know is from a ceratopsian. At a later date Leidy became aware of the fact that these two teeth were quite different and in 1868 (4) he stated:

> Perhaps this specimen (the double-rooted tooth, Figures 18–20) belongs to another dinosaur for which the name *Trachodon* might be reserved while that of *Hadrosaurus* might include the first mentioned (Figures 1–3) and more characteristic tooth.

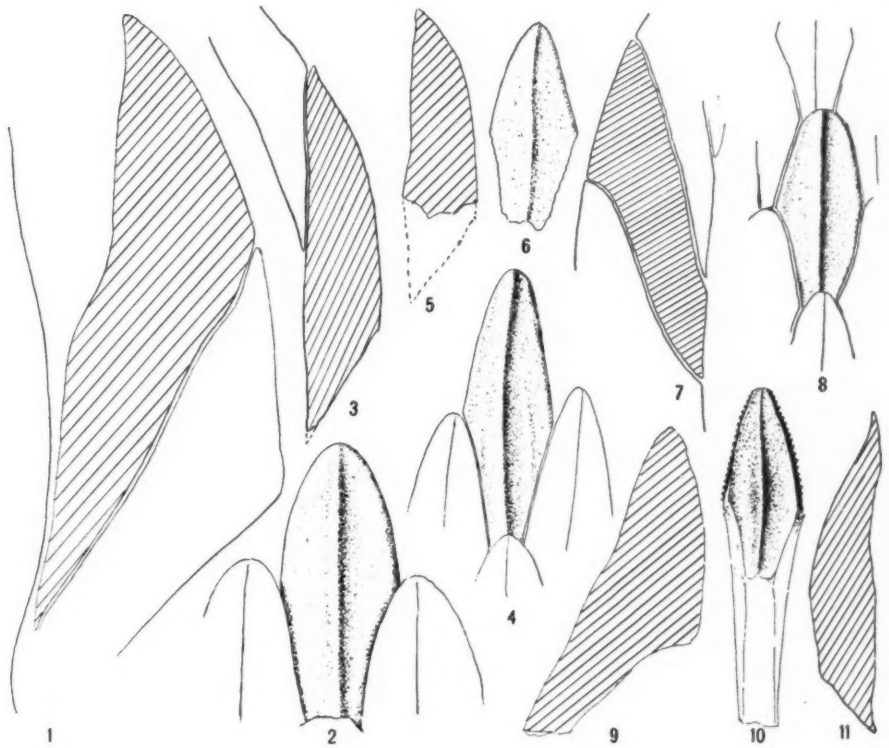
From this time on Leidy referred to this tooth as *Hadrosaurus*.

Cope, believing Leidy had abandoned the genus *Trachodon*, described a new genus and three new species as *Diclonius pentagonus*, *D. perangulatus*, and *D. calamarius*, based on shed teeth from the Judith River beds of Montana. In 1883 Cope referred the species *mirabilis* to his genus *Diclonius* and at the same time described the skull of a Lance form which he referred to *Diclonius mirabilis* (5).

Several of the earlier palaeontologists believed that the Judith River and Lance were contemporaneous, and no doubt this is why Cope referred the Lance skull to Leidy's Judith River species. Although Leidy abandoned the use of the name *Trachodon* for the single-rooted tooth, several later workers prefer to retain it and some use it to include the flat-headed, duck-billed dinosaurs of Lance age. If the genus is to be retained, it is important to determine, if possible, its systematic position

within the family, and obviously this must be done from a study of Leidy's type. It is with this in mind that the present study has been made. As it is well recognized that Leidy's specimen is from the dentary, only dentary teeth have been considered.

the dentary teeth is relatively shorter. One feature of the dentary teeth has not been stressed but nevertheless appears to offer diagnostic characters, the lingual-buccal section. It is believed that the flat-headed forms can be separated easily



FIGS. *1, 2—Gryposaurus* sp. Vertical section of part of dental magazine showing posterior view of tooth; enamel face of dentary tooth.
3, 4—Lambeosaurus clavinitialis. Vertical section and enamel face of dentary tooth.
5, 6—Trachodon mirabilis. Vertical section and enamel face of type, drawn from cast.
7, 8—Thespesius sp. Vertical section and enamel face of dentary tooth from the Edmonton formation.
9, 10—Hadrosaurus foulkii. Vertical section and enamel face of dentary tooth, drawn from Leidy's figure.
11—Chenosaurus tolmanensis. Vertical section of dentary tooth.
All figures natural size.

It has been generally recognized that in the flat-headed forms (Hadrosaurinae) the teeth are more numerous and that the enamel face of

from the hooded forms by a study of this vertical section of the dentary teeth.

Through the courtesy of Dr. R. S.

Lull I secured a splendid cast of the single-rooted tooth that Leidy included in his type material of *Trachodon mirabilis*, and photographs of the original specimen, now in the collections of the Academy of Natural Sciences of Philadelphia (cat. no. 9260). Vertical sections were made of several dentaries that could be identified as to genus, so as to show the section, from within outward, of the dental magazine and the teeth. Included in this lot are *Lambeosaurus* (Figs. 3, 4) and *Gryposaurus* (Figs. 1, 2) from the Belly River formation, and *Cheneosaurus* (Fig. 11) and *Thespesius* (Figs. 7, 8) from the Edmonton formation. Then there are Leidy's figures of *Hadrosaurus* (6) and Marsh's figures of *Thespesius* (*Claosaurus*) *annectens* (7). It is generally conceded that *Hadrosaurus foulkii* belongs with the flat-headed forms, the Hadrosaurinae. *Gryposaurus* and *Thespesius* also belong to this subfamily, whereas *Lambeosaurus* and *Cheneosaurus* belong with the hooded forms, the Lambeosaurinae.

In all of the flat-headed forms the dental magazine is relatively much thicker than in the hooded forms, a difference due to the respective sizes and shapes of the roots, or fangs, of the teeth. When viewed from the front or back, the vertical outline of the dentary teeth of the flat-headed forms makes an obtuse triangle, with the shorter sides formed by the enamel face and the margin of the fang below it (Figs. 1, 7, 9). The fang runs diagonally away from the upright enamel face, and the width of the vertical section, at the base of the crown, is greater than the greatest width of the enamel face. These features are very well shown in Leidy's illustration of *Hadrosaurus foulkii* (Figs. 9, 10) and he drew attention to them (8). They are also well shown in the Belly River *Gryposaurus* and the Edmonton *Thespesius*.

In the dentary teeth of the hooded forms the fang is not deflected at so sharp an angle, with the result that the internal and external faces are nearly parallel, and the fang continues downward from the enamel face in a gentle curve (Figs. 3, 11). In the functional tooth the fang carries down as a long, thin wedge, but in the younger teeth it is not so well developed. This downward continuation and thinning of the fang make the space occupied by the teeth less, and thus the dental magazine is much thinner than in the flat-headed forms. The diameter from within outward at the base of the enamel crown is less than the greatest width of the crown, even though the enamel face is relatively narrow and long.

A study of the cast and photographs of Leidy's specimen (Figs. 5, 6), as well as illustrations of the tooth in his *Cretaceous reptiles of the United States* (his figures 12–14), show that this tooth is from a hooded form. Although it is difficult to determine genera and species of hadrosaurs from single teeth, this tooth meets all requirements of the Lambeosaurinae and is quite different from the teeth of any flat-headed

form studied. It would seem, then, that if *Trachodon* is to be regarded as a valid genus it must be referred to the subfamily Lambeosaurinae and should not be used for the reception of flat-headed forms.

In the teeth that I have been able to study, those of the flat-headed forms are solid or nearly so—in other words, there is no pulp cavity remaining except in the younger teeth; whereas in the hooded forms the pulp cavity persists until the tooth comes into use. This study has not been carried far enough, however, to ascertain if these are dependable characters. Leidy observed the difference between *Trachodon* and *Hadrosaurus*.

As we now know that *Hadrosaurus* is not a synonym of *Trachodon*, there is no excuse for using Trachodontidae as a family name, as is sometimes done, instead of Hadrosauridae, which was proposed by Cope and used by Marsh, Zittel, and others several years before Trachodontidae was proposed. The subfamily name Trachodontinae, as proposed by Brown (9), can not be used because his definition does not fit the hooded forms of the group, those with which *Trachodon* must be associated.

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JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 7, PP. 656–659, 5 TEXT-FIGS., OCTOBER, 1936

UPPER DEVONIAN FISH FROM COLORADO

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ABSTRACT

Fragmentary remains of fish from four localities in the Chaffee formation of Colorado represent elasmobranchs, arthrodires, crossopterygians, and dipnoans; three species are new.

During the summer of 1934 Mr. Johnson in connection with work for the U. S. Geological Survey, collected a number of fragments of fossil fish from the Devonian of central Colorado. These specimens have been examined by Mr. Bryant, who contributes to the present paper the descriptions of the material. Mr. Johnson contributes the statement concerning the localities and the stratigraphic horizons.

OCCURRENCE

BY J. HARLAN JOHNSON

The fish remains described in this paper were obtained from four localities, all in central Colorado:

1. Along Gribbles Creek in T. 51 N., R. 11 E., Fremont County.
2. In cirque above Boulder Lake, at north end of Fossil Ridge, in approximately sec. 11, T. 51 N., R. 3 E., Gunnison County.
3. On eastern side of Cross Mountain in sec. 20, T. 15 S., R. 83 W., Gunnison County.
4. Along Deadman Creek in sec. 14, T. 14 S., R. 84 W., Gunnison County.

The fossils came from the lower member of the Chaffee formation. This member corresponds to the Parting quartzite member (1) of the Mosquito Range and to the Elbert formation of the San Juan Region (2). At locality 1 the fossils were found in a light yellow-gray dolomitic sandstone about 20 feet above the base of the member. At locality 2 they were obtained from the basal conglomerate and from sandy layers extending to ten feet above the base. At locality 3 they came from a sandstone and edgewise conglomerate about 82 feet above the base, at the very top of the lower member of the Chaffee formation. At locality 4 they were obtained from a thin sandstone 19 feet above the base of the formation.

These fossils are of stratigraphic as well as paleontologic importance, for the fossils hitherto obtained from the Chaffee formation were all found in the upper part of the lower member or in the upper member. At localities 1, 2, and 4 the fossils came from horizons near the base of the formation; at locality 2 some were obtained from the very base of the formation. It is noteworthy that the remains came from sandstones and sandy dolomites, and that none were found in the shales, shaly dolomites, or pure limestones and dolomites.

THE FOSSILS

BY WILLIAM L. BRYANT

Although the remains are fragmentary and often badly eroded, one can distinguish among them the spines and pavement teeth of elasmobranchs, fragments

of arthrodire plates, the scales and teeth of crossopterygian fishes and the dental plates of dipnoans.

CROSSOPTERYGIAN REMAINS

The most abundant material consists of detached scales, jaw fragments, head bones, and teeth of a large crossopterygian fish. The scales are boldly sculptured in a reticulated pattern of pits and ridges, formed by coarse and confluent tubercles. Thin sections of scales and teeth show that the minute structure is poorly preserved. However, it is certain that the teeth, while vertically folded at the base, exhibit none of the complex infolding of the dentine walls so characteristic of the Holoptychidae. On the contrary, the pulp cavity is fairly large at the base and the dentine structure simple. Perhaps the nearest American relative of this fish is *Glyptopomus sayerei* Newberry, from the Catskill rocks of Pennsylvania. Examples were found at localities 1, 2, and 4.

ELASMOBRANCH REMAINS

Three small, broken spines (U. S. Nat. Mus. 13821–13823), all evidently of the same species, belong in the genus *Ctenacanthus*. All of them lack both the apex and the base of insertion and are too fragmentary for complete description. These spines, no doubt, were long, slender, slightly curved, and laterally compressed. The pulp cavity is large, extending almost to the apex. The sides are ornamented by eight or ten prominent longitudinal ridges, some of which are intercalcated near the base. Each of these ridges bears a series of tubercles separated from each other by a distance about equal to the width of the tubercles. No posterior denticles are preserved. All of these spines were collected at locality 1.

Only one other elasmobranch fossil occurs in the collection. This is the small cochliodont tooth, largely composed of upright tubes of dentine, described below as a new species of *Sandalodus*.

SANDALODUS MINOR Bryant, n. sp.
Figure 1

Holotype: A small dental plate in sandstone (U. S. Nat. Mus. 13810).

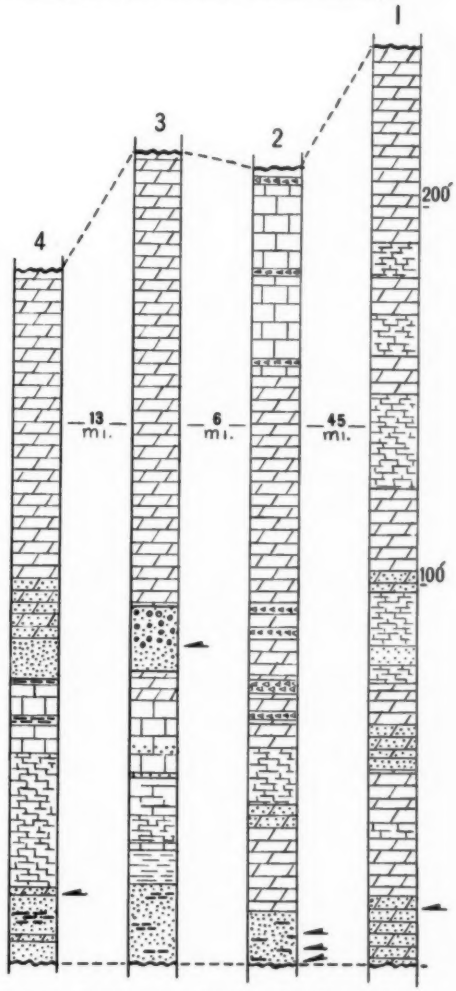

FIG. 5—Sections of the Chaffee formation at the four localities from which fish remains are recorded in this paper. The arrows indicate the horizons of the specimens. Lithologic character of the subdivisions of the formation is represented by the usual conventions.

Tooth small, spatulate in outline; one extremity broad and evenly rounded, the other acute and slightly twisted. Coronal

surface gently arched in both directions without ridges or furrows and covered with a shining coat of punctate enamel.

The unique tooth upon which this species is founded is very small, measuring only 12 mm. in length. The tritoral surface is covered throughout with punctae, uneven in size and frequently confluent, thus giving the surface a slightly rugose appearance. While not exposed, the base of this tooth is probably slightly concave.

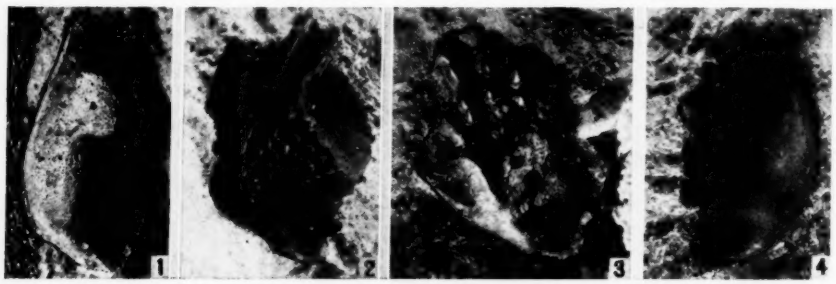

FIG. *1*—*Sandalodus minor* Bryant, n. sp., holotype tooth, ×2.6; U. S. Nat. Mus. 13810 (p. 657)
2—*Dipterus johnsoni* Bryant, n. sp., holotype, left upper dental plate, ×1.6; U. S. Nat. Mus. 13811. (p. 658)
3—*Dipterus johnsoni* Bryant?, incomplete right lower dental plate, showing evidence of considerable functional erosion, ×1.6; U. S. Nat. Mus. 13817. (p. 658)
4—*Conchodus parvulus* Bryant, n. sp., holotype dental plate, ×3.3; U. S. Nat. Mus. 13812. (p. 659)

The nearest American relative of this species is *Sandalodus carbonarius* Newberry and Worthen, from the coal measures at La Salle, Illinois. It also resembles in some respects *Deltodus spatulatus* Newberry and Worthen, from the lower Carboniferous of Illinois and Indiana. From both of these species, however, it differs in several characters.

Although the various species of *Sandalodus*, so far as known to the writer, have only been recorded from the Carboniferous, at least one member of the family, *Helodus simplex* Agassiz, has been found in the Upper Devonian of Missouri.

The present specimen was found at locality 1.

ARTHRODIRAN REMAINS

Fragments of the dermal armor of at least two large species of arthrodires occur in the collection. There are no complete plates, but thin sections show the characteristic structure of arthrodire bones. These plates are of the tuberculate type. Two fragments bear on their outer surface the large, discrete tubercles found in the Upper Devonian genus *Aspidichthys* (U. S. Nat. Mus. 13819). Another fragment (U. S. Nat. Mus. 13818) exhibits the smaller but still coarse tubercles found in several species of *Dinichthys*, for instance, *Dinichthys tuberculatus* Newberry, from the Chemung of Pennsylvania and the Upper Devonian of Wisconsin. Such ornamentation, however, is unsafe as a diagnostic character.

All of the arthrodire fragments were found at locality 1.

DIPNOAN REMAINS

DIPTERUS JOHNSONI Bryant, n. sp.
Figure 2, 3

Types: Holotype, a left upper dental plate in sandstone (U. S. Nat. Mus. 13811); paratypes, U. S. Nat. Mus. 13813, 13816.

The dental plates are of small size, about 18 mm. in length.

The coronal surface has about seven nearly straight, radiating rows of tubercles extending almost to the postero-inner angle. Counting from the front of the plate, the second and third tuberculate rows are much the largest and long-

est. The outer tubercles in each row are laterally compressed, while the inner ones are obtusely rounded. The coronal surface of the upper dental plates is gently concave, that of the lower plates is convex.

The functional area of the type specimen is crossed by seven diverging rows of tubercles that originate close to the postero-lateral angle. The individual tubercles vary greatly in size and shape, the outermost being strongly compressed laterally, while the inner ones are broadly rounded, some being wider than long. In some cases their bases are confluent.

Two or three other smaller and, no doubt, juvenile plates from the same locality are preserved in the collection. Except for size they are indistinguishable from the type.

An incomplete right lower dental plate (U. S. Nat. Mus. 13817) of a size comparable with the type is ascribed doubtfully to the present species. It shows evidence of functional wear. Only four or five rows of tubercles are preserved and of these the inner ones are worn down to the base. Here, too, the outer tubercles are compressed, while the inner ones are broadly rounded and sometimes confluent. The functional surface of the plate is convex and the plate itself is thicker and more robust than the upper plate. Owing probably to functional erosion, only one row of tubercles can be traced to the postero-inner angle of the plate and in its present condition there is a superficial resemblance to a plantigrade foot. The margins are not complete and originally there may have been one or two additional small rows of tubercles that have now disappeared. Better specimens of this lower dental plate may prove it to be a distinct form.

This species is named in honor of its discoverer, Mr. Johnson.

Three of the specimens were found at locality 3; one (13813) at locality 1.

CONCHODUS PARVULUS Bryant, n. sp.
Figure 4

Holotype: A small dental plate in sandstone (U. S. Nat. Mus. 13812).

The dental plate is of small size, the functional surface is crossed by about four broad, smooth, non-tuberculate plications, radiating fanwise to the outer border.

The unique ovate dental plate measures only 8 mm. in greatest length by 4 mm. in width, and may well represent a juvenile individual.

The broad, smooth vestigial plications show no evidence of tuberculation, and become more prominent as they approach the outer border of the plate. The specimen is evidently a mandibular element, as indicated by the strongly convex surface.

Only one species of this rare genus has hitherto been described from America, the somewhat doubtful *Conchodus variabilis* Eastman, from the Upper Devonian of Johnson County, Iowa. The latter species never displays more than one or two marginal plications and to the present writer seems to have nothing to do with the splenial or palatine dental elements of dipnoans, but instead to have formed part of the dental pavement of a Paleozoic shark.

The type specimen of *Conchodus parvulus* was found at locality 3.

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JOURNAL OF PALEONTOLOGY, VOL. 10, NO. 7, PP. 660–662, 2 TEXT-FIGS., OCTOBER, 1936

FOOTPRINTS IN LATE PALEOZOIC RED BEDS NEAR BOULDER, COLORADO

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ABSTRACT

One trackway, probably of an invertebrate, from the Lyons sandstone (Pennsylvanian or Permian) shows clusters of three prints on each side of a median trace. Tracks from the Fountain formation (Pennsylvanian) show three toes and four toes and may represent fore and hind feet of an amphibian. Both seem to be unrecorded forms.

Although vertebrate remains have been discovered in the Late Paleozoic red beds of many localities in the west and southwest, the equivalent formations of the foothills region of Colorado are decidedly lacking in evidence concerning the life of the time. The only unquestioned vertebrate remains described are footprints from the Lyons Sandstone named *Limnopus? coloradensis* by Junius Henderson (1).

The Paleozoic section of north-central Colorado includes the following formations, in ascending order: Fountain formation, consisting of from 500 to 1500 feet of alternating red arkosic conglomerate, arkose, and micaceous sandy shale of Pennsylvanian age; Lyons sandstone, about 200 feet of pink to cream-colored sandstone of Pennsylvanian or Permian age; and the Lykens formation, made of up to 800 feet of brick-red shale and sandy shale with occasional limestones of peculiar character, known as "crinkly." The age of the Lykens formation may be Permian, but conclusive evidence is thus far lacking. South of Fort Collins, this entire section is predominantly of non-marine origin; northward, marine limestones of probable Pennsylvanian age occur above and below the Lyons. The formations outcrop as a broad band paralleling the mountain front and are sharply inclined to the east in most places.

PALEOHELCURA? LYONSENSIS Toepelman and Rodeck, n. sp.

Figure 1

Some months ago, Mr. Adair Fehlman, of Boulder, presented to the University of Colorado Museum a small slab of Lyons sandstone showing a perfect trace of a trail of a type not previously seen in the formation. The slab was not found in place and its exact position in the Lyons section cannot be stated, but the lithology of the formation is so characteristic that there can be no question of the specimen's having come from it.

The trail consists of two parallel lines of tracks between which is deeply and clearly impressed the trace of either a very sharp caudal appendage or a sharp spine or keel on the ventral surface of the animal. The two lines of tracks are made up of clusters of three sharply impressed prints. The longer axis of the majority of clusters is almost at right angles to the line of the median trace. The width of the entire trackway averages about 24 mm.; the length of the preserved portion is approximately 190 mm. The average width of the clusters of three is almost

8 mm., and the average stride is exactly the same. In the majority of clusters the median print is distinctly in front of the two lateral ones. Both lateral prints are slightly inclined from the middle. There is very little difference in the size of the individual prints, the length averaging 4 mm., the width, 1.5 mm.

Although the trackway is remarkable for its perfection of detail, the writers are reluctant to refer it to any particular group of animals. The sharply incised character of the "tail" trace and the complete absence of palm or foot impression makes it highly improbable that the tracks are of vertebrate origin. The writers are inclined to agree with Prof. T. D. A. Cockerell, who, after examination of the specimen, suggests that it might possibly be the trail of a crustacean or an arachnid-like form. Although these groups possess more than three pairs of appendages, it is conceivable that some use only three pairs for locomotion. In spite of the inability to classify the tracks, their remarkable perfection and unusual character make it desirable that they be described and named.

The only tracks so far described that even remotely resemble those under discussion are those described by Gilmore from the Coconino sandstone on the Hermit Trail in the Grand Canyon under the name of *Paleohelcura tridactyla*(2). This species is similar only in the tridactyl character of the prints and the presence of a very distinct trail trace The pattern of the three print clusters is quite different, the clusters of *Paleohelcura tridactyla* having the long axis aligned at an angle of 45° to the line of direction rather than at right angles as in the present specimen. Likewise, in the former the inner print is definitely smaller than the outer two, whereas in our track the prints are of nearly equal size. Although it is improbable that the two sets of prints were made by closely related species of a single genus, to avoid multiplicity of names for specimens of doubtful systematic position, the tracks are provisionally named *Paleohelcura? lyonsensis.*

FIG. 1—*Paleochelcura? lyonsensis* Toepelman and Rodeck, n. sp., holotype trackway, ×0.44, Lyons sandstone near Boulder, Colorado.

BRACHYDACTYLOPUS FONTIS Toepelman and Rodeck, n. gen. and sp.

Figure 2

Until very recently, the Fountain formation at Boulder had yielded no recognizable fossil remains of any kind. Late in the fall of 1934, in the course of road building on Flagstaff Mountain, west of Boulder, an outcrop of a shaly sandstone was uncovered, on which are impressed several score footprints made probably by amphibians. Most of the tracks are imperfect and indistinct, but at least one

type is sufficiently clear to justify description. The bedding plane containing the tracks is lightly ripple-marked and shows suggestions of suncracks. The prints are irregularly scattered over about forty square feet of surface. The more perfect have been removed and placed in the University of Colorado Museum.

FIG. 2.—*Brachydactylopus fontis* Toepelman and Rodeck, n. gen. and sp., restoration drawn from the holotype prints, ×¼, Fountain formation, Flagstaff Mountain, west of Boulder, Colorado.

Because of the irregular scattering of the tracks, it has been impossible to identify a trackway and stride; neither is it possible to be sure of fore and hind foot. No suggestion of a tail or body trace is visible. The best track, that which serves as the basis for the accompanying figure, is 114 mm. long and 107 mm. wide. Four short stubby toes have been deeply impressed into the sediment. The toes are broadly rounded in front and apparently were not equipped with claws. The left toe is separated a bit more than are the remaining three, suggesting that this is the print of a right limb, possibly the right manus. From left to right the digits have the following lengths: 18 mm., 26 mm., 25 mm., 23 mm. The palm, if this be the manus, is but slightly impressed into the surface, so that the outline shown can be considered only as approximate.

As indicated in the figure, an impression of three toes lying in front of the four-toed track and considerably more elongate than those described may be the imperfect print of the other limb, lacking the imprint of the sole.

The impressions here described resemble most closely those of the several described species of the genus *Baropus* Marsh (3). In *Baropus* the breadth is considerably greater than the length, whereas in the present specimen breadth and length are much the same; in *Baropus* the toes are proportionally longer than is the case here; and finally, the second, third and fourth digits of *Baropus* are of different lengths. It is, therefore, not probable that the form here described is to be placed in that genus, and the name *Brachydactylopus fontis* is proposed.

On the surface with *B. fontis* are a few tracks with quite similar outlines and characteristics except that they are only about one half as large. These are considered to be impressions left by an immature individual of the same species. Still a third kind of track, almost circular in outline and about the size of that of an ordinary house cat is present, but the details are so obscure that description is not justified. All three types are but slightly impressed into what must have been a very soft sediment. This suggests the interesting possibility that the animals responsible for the impressions were partially supported in water and did not exert their entire weight on the bottom sediment.

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PALEONTOLOGICAL NOTES

ARE CONODONTS GASTROPODS?

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For some years paleontological literature has been sprinkled with descriptions of the tiny bodies called "conodonts." They may be characterized briefly as tiny teeth, ranging in size from a quarter of a millimeter to a little over a millimeter, of horny or chitinous composition, occurring in great numbers in certain types of sediments, and, so far reported only from Paleozoic formations. From the introduction to a recent paper by Stauffer (1) on Ordovocian conodonts we further glean that it is quite probable that several types of teeth belonged to a single individual . . . the denticles are inserted into the base and are only secondarily a part of it . . . [the base is attached] to skeletal parts that are not bone, but a material similar in composition to that of the teeth themselves.

The forms are readily distinguishable and have proved good horizon-markers; and they are particularly useful to micropaleontologists because they are still recognizable in the pulverized rock of well-drillings.

Their relationships have not been established, though suggestions have been made that they are the radular teeth of mollusks, the jaws of annelid worms, and teeth from the gill rakers of fish. H. W. Scott (2) has reviewed the literature on relationships of the conodonts, which shows a leaning of opinion toward the thesis of derivation from primitive fishes, but Scott himself has added new and interesting observations and has concluded that the fossils are remains of annelid worms.

In going over the radulae of certain snails, the similarity, noted as long ago as 1884 by James (3), of the individual radular teeth to individual conodonts was strongly impressed on the writer. These tiny gastropod denticles, ranging in size from a quarter of a millimeter to a millimeter, composed of horny or chitinous material, occurring by hundreds to tens of thousands per individual gastropod, with several types of teeth on each radula, and the teeth inserted quite firmly on a ribbon of the same sort of material, may well be what, when found as fossils, are called conodonts.

Naturally the teeth of land and freshwater snails and those of the more highly specialized types are less suitable for comparison with Paleozoic genera of marine conodonts. Figure 1 shows sets of the teeth as they occur on the radulae of gastropods. Such genera as *Buccinum*, *Nassa*, and *Fulgur*, as is typical for part of the snails, possess a median row with a lateral row on either side. The median teeth suggest such conodont genera as *Lonchodus* and *Neocoleodus;* the lateral teeth are strikingly like such genera as *Cyrtoniodus* and *Subcordylodus. Buccinum*, *Fulgur*, and similar genera have 110 to 125 sets of teeth on the radula. In such genera as *Trochus* and *Haliotis* much more variety is found, there being a central row, five rows of laterals on either side, and outside of these some 30 marginal rows of teeth. These marginals, when isolated, show considerable range of form and resemble such conodont genera as *Oistodus* and *Paltodus*. Each *Trochus* has 125 to 140 sets of teeth on the radula, making as many as 10,000 teeth per individual. So far I have seen no conodonts to match the central and lateral teeth of *Trochus*, but it would be surprising if all the modern forms were represented in the Paleozoic or vice versa. *Haliotis* has some lateral teeth suggestive of the rather unusual forms of conodonts like *Polycaulodus*.

To the writer it seems impossible that teeth so close in size, shape, and composition as those of the conodonts and the gastropods can belong to anything but the same group of organisms. There will doubtless be found conodonts in the Mesozoic and later deposits, if sought.

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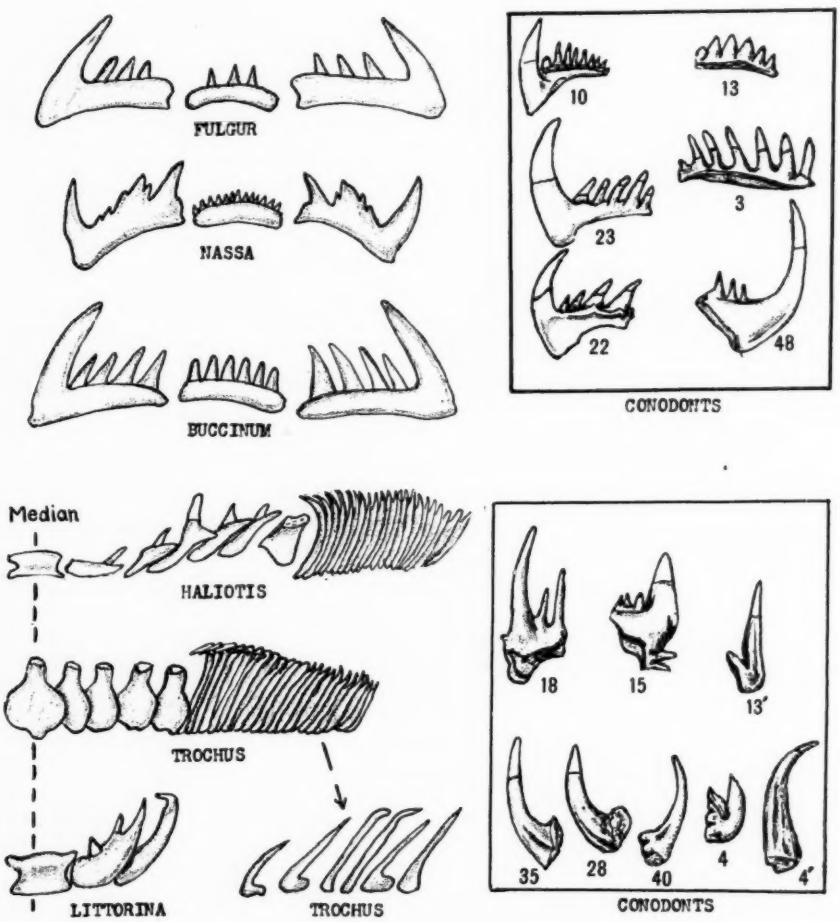

FIG. 1—The teeth to the left are those of modern gastropods of the genera indicated; those to the right are Ordovician conodonts, after Stauffer. Both sets approximately ×20. The numbers are Stauffer's, as follows: Pl. 72, fig. 3, *Lonchodus*?; fig. 13, *Neocoleodus*. Pl. 73, fig. 10, *Cyrtoniodus;* fig. 22, *Subcordylodus*?; fig. 23, *Subcordylodus;* fig. 48, *Prioniodus*. Pl. 74, fig. 4′, *Paltodus;* figs. 28, 35, 40, *Oistodus*. Pl. 75, fig. 4, 13, *Oistodus;* fig. 15, *Pteroconus;* fig. 18, *Polycaulodus*. (p. 663)

ADDITIONAL NOTES ON THE MOLLUSCAN FAUNA OF THE PLIOCENE CROATAN SAND OF NORTH CAROLINA

BY W. C. MANSFIELD
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Since the publication of my paper, "Notes on Pleistocene faunas from Maryland and Virginia and Pliocene and Pleistocene faunas from North Carolina," published as U. S. Geological Survey Professional Paper 150-F, 1928, additional Pliocene material has been obtained from one locality in Craven County and from four localities in Onslow County, N. C.

The Craven County locality, which is on the right bank of the Neuse River, 2 miles below James City, is important because some of Conrad's type material came from there. The Onslow County localities are also important because the faunas show a relationship both to the Pliocene faunas along the James River at the north, and on or adjacent to the Cape Fear River to the south.

DESCRIPTIONS OF STATIONS

The localities and the character of the fossil-bearing beds are described below:

U. S. Geol. Survey No. 13812, On property of Mr. Hastings, right bank of Neuse River, 2 miles below James City, Craven County, N. C. W. C. Mansfield and F. S. MacNeil, collectors, April 24, 1936. A few additional species were collected by S. F. Blake, who called our attention to this place. (Locality referred to in the list as "near James City.")

The fossiliferous bed here is about 15 feet thick and extends along the river for a distance of about 100 yards. The sediments are bluish when wet and gray when dry and consist mainly of medium sized quartz sand mixed with a minor amount of clay.

U. S. Geol. Survey No. 13811. Highest fossiliferous bed in a marl pit on the A. W. Askews farm, one-half mile east of highway and 2 miles northwest of Silverdale, Onslow County, N. C. W. C. Mansfield and F. S. MacNeil, collectors, April 23, 1936. (Locality referred to "near Silverdale" in list.)

The bed in which the Pliocene shells occur is about 3 feet thick and rests unconformably on the fossiliferous Trent marl. The lower part of the Pliocene bed contains well rounded quartz pebbles, some of which are 1 inch or more in length, and phosphatic pebbles. The matrix in which the shells are embedded is a yellow, coarse-grained quartz sand. The Pliocene bed was observed in only one pit.

U. S. Geol. Survey No. 1/940 (L. B. Kellum); 11740 (C. W. Cooke); 11996 (W. C. Mansfield and F. S. MacNeil). Marl pits on the farm of Jackson Jones at the edge of a swamp of Grants Creek (tributary of White Oak River) about 100 yards to the left of the old road from Jacksonville to Maysville, about 9 miles south of Maysville and 5 miles west of Silverdale, Onslow County, N. C. (Locality referred to "Grants Creek" in list.)

The bed in which the Pliocene fossils occur consists mainly of sand, is 3 to 5 feet thick and rests unconformably on the Trent marl.

U. S. Geol. Survey Nos. 1/941 (L. B. Kellum); 11998 (W. C. Mansfield). Two miles north of Padgett and about 6 miles southwest of Verona, Onslow County, N. C. (Fauna from this locality combined with that from 11997 in list.)

U. S. Geol. Survey No. 11997. Marl pits on the W. M. Parker place, about 5½ miles southwest of Verona and about 2½ miles north of Padgett, Onslow County, N. C. W. C. Mansfield, collector. (Fauna from this locality combined with that from 11998 in list.)

The Pliocene bed consisting of a dark-gray coarse-grained sand in the vicinity of Padgett is very thin and apparently occupies depressions in the underlying bed. The underlying bed may be the Trent marl as this marl crops out on Stones Creek about 4 miles east of Padgett and 1 mile east of Dixon.

LIST OF SPECIES

The following is a list of species from the localities in Craven and Onslow counties with an indication of those which are common to Wilmington and to the Waccamaw formation. Those marked "A" are from near James City; "B," Grants Creek; "C," near Padgett; "D" near Silverdale; "E," common to Wilmington; and "F" common to the Waccamaw formation.

GASTROPODA:

Acteocina canaliculata (Say), A, B, D, E, F
Ringicula sp., A
Terebra concava (Say), B, F
Terebra neglecta Emmons, B
"Drillia" aff. *D. sumterensis* Gardner and Aldrich, C
Mangelia eritima Bush, B, F
Olivella nitidula Dillwyn, B, E, F
Marginella contracta Conrad, B, E, F
Marginella bella Conrad, B, E, F
Marginella aureocincta Stearns, B, D, E, F
Marginella limatula Conrad, A, B, E, F
Cypraeolina dacria (Dall), B, D, E, F
Scaphella (Aurinia) obtusa Emmons, B, C, E, F
Mitra wandoensis Holmes, B, D, E, F
Busycon perversum (Linnaeus), B, E, F
Alectrion vibex (Say), B
Alectrion consena (Ravenel) var.?, B, D, E, F
Ilyanassa irroata Conrad, A, B, C, D, E, var., F
Ilyanassa porcina Say?, B
Anachis obesa C. B. Adams, A, B, E, F
Anachis avara translirata Ravenel, A, B, D, F
Mitrella lunata (Say), A, B, F
Eupleura sp., A, B
Urosalpinx (?) sp., B
Urosalpinx sp. aff. *U. perrugatus* Conrad, A
Muricidea sp., B
Epitonium sayanum Dall?, A, B
Melanella sp., B
Melanella sp., A
Turbonilla (1 or more species), A, B
Odostomia impressa (Say), A, B
Odostomia cf. *O. seminuda* C. B. Adams, A, B, D
Triforis sp., A
Cerithopsis sp., B
Seila adamsii (H. C. Lea), A, B, D, F
Caecum flemingi Gardner and Aldrich, B, D, E, F
Caecum regulare Carpenter, B
Caecum cooperi S. Smith, B, D, E cf.
Vermicularia spirata (Philippi), A, B, F
Turritella subannulata Heilprin, B, C, E, F
Littorina irroata carolinensis Conrad, B, C, E, F
Crepidula plana Say, A, B, E, F
Crepidula aculeata Gmelin, C
Crepidula fornicata (Linnaeus), B
Crepidula fornicata ponderosa H. C. Lea, B, C, D, E, F
Polinices (Neverita) duplicatus (Say), A, B, C, E, F
Tectonatica pusilla (Say), A, B, D, E
"Solarorbis" undula Dall, A, B,
Circulus sp., B, D, E
Diodora alternata (Say), A, B, C, D, E, F

PELECYPODA:

Nucula proxima Say, A, B, C, D, E, F
Nuculana acuta (Conrad), A, B, C, D, E, F
Yoldia sp. (small), B
Glycymeris pectinata (Gmelin), B, C, E, F
Glycymeris americana (DeFrance), B, C, E, F
Arca "subsinuata" Conrad, A, B, C, D, cf. F
Arca (Anadara) lienosa Say, C, E, F
Arca (Noetia) limula Conrad, A, B, C, aff. E
Fossularca adamsi Dall, A, B, C, D, E, F
Ostrea sculpturata Conrad, A, B, D, E, F
Ostrea virginica Gmelin, B, ?C
Pecten eboreus cf. *solaroides* Heilprin, A, B, C, D, E, F
Pecten cf. *P. sentis* Reeve, A
Pecten aff. *evergladensis* Mansfield, C, E, F
Plicatula marginata Say, ?A, B, C, D, E, F
Anomia simplex D'Orbigny, B, F
Mytilus sp., B
Pandora trilineata Say, B, F
Astarte concentrica bella Conrad, C, E, F
Astarte n. sp.?, B
Crassatellites gibbesii (Tuomey and Holmes) C, E, F
Crassinella lunulata (Conrad), A, B, D, E, F
Cardita arata (Conrad), A, B, C, E, F
Venericardia perplana abbreviata (Conrad), A, B, C, D, E, F
Venericardia granulata Say, B, C, E, F
Venericardia tridentata decemcostata Conrad, B, C, D, E, F
Chama striata Emmons, A, B, D, E, F
Echinochama arcinella (Linnaeus), B, C, F
Phacoides radians Conrad, B, C, E, F
Phacoides anodonta (Say), B, C, E, F
Phacoides multilineatus (Tuomey and Holmes), A, B, D, E, F
Phacoides waccamawensis delandensis Mansfield, A, B
Divaricella quadrisulcata (D'Orbigny), B, C, E, F
Diplodonta caloosaensis Dall, B, D, E, F
Diplodonta acclinis (Conrad), B, C, F
Bornia triangulata Dall, A, F
Erycina carolinensis Dall, B, E, F
Sportella protexta (Conrad), A, F
Sportella constricta (Conrad), A, B, E, F
Aligena aequata (Conrad), B, D, E, F
Cardium robustum Solander, A, B, D, ?E, F
Cardium isocardia Linnaeus, B, E, F
Transenella carolinensis Dall, A, B, D, E, F
Gafrarium (Gouldia) metastriatum (Conrad), B, E, F
Macrocallista reposta Conrad, B, E, F
Callocardia sayana (Conrad), A, B, C, D, E, F
Chione athleta Conrad, B, C, E, F
Chione cribraria (Conrad), B, C, E, F
Chione cancellata (Linnaeus), C, F
Venus rileyi Conrad, A, B, ?C, F
Gemma trigona Dall, B, F
Gemma magna Dall, B, E, F

Parastarte cf. *P. triquetra* (Conrad), B
Tellina propetenella Dall, B, E, F
Tellina sayi Dall, B, E, F
Cumingia tellinoides (Conrad), A, F
Abra aequalis (Say), A, B, D, E, F
Donax fossor Say, B, C, F
Ensis sp., A, B,
Spisula subparilis Conrad, B, C, D, E, F
Mulinia lateralis Say, A, B, C, E
Mulinia magnoliana (Dall), B, F
Corbula inaequalis Say (Small form like var. *B*, at Deland), A, B, D, E, F
Corbula inaequalis Say (Larger form, like var. *A* at Deland), A, C
Corbula contracta Say, B, F
Corbicula densata Conrad, B, E, F
Anisothyris cf. A. obliqua Gabb, B
Rangia clathrodonta (Conrad), B, C, E, F
Panope goldfussii Wagner, var.?, A
"*Gastrochaena*" *cuneiformis* Spengler, A
Sphenia cf. *dubia* H. C. Lea, A, ?B

CONDITIONS ATTENDING DEPOSITION

Prior to the invasion of the Pliocene sea, as shown by the relation of the deposits at station 13811, 2 miles northwest of Silverdale and at station 11996, Grants Creek, Onslow County, N. C., the area appears to have been above sea level for a considerable length of time, for here the Pliocene bed rests unconformably on the Trent marl of lower Miocene age. However, the time interval represented by the unconformity here was not so long as that to the south along the Cape Fear River, on the northern shore of Lake Waccamaw and at Acme, N. C., for at those places the Pliocene bed rests unconformably on the Cretaceous.

The Pliocene bed in Onslow County is thin and appears to occupy depressions in the underlying Trent marl. The original thickness of this bed may have been greater than now, the sediments having been eroded away during a subsequent uplift.

Along the Neuse River, below James City, the exposed thickness of the Pliocene bed above the stream level is 15 feet. The total thickness here has not been determined, but the Trent marl, upon which the Pliocene sand rests, is probably not far below the stream level.

NOTES ON THE CHARACTER OF THE FAUNAS

The pelecypods outnumber the gastropods both as to the number of species and the individuals of the species. Fifty species of gastropods and 71 species of pelecypods are listed in this paper. Among the gastropods, the genus *Marginella* is represented by four species and each species by several individuals. The families, Alectrionidae and Columbellidae, are each represented by two genera and the species of each genus by several individuals. The genus *Crepidula* is represented by three species and one variety, including many large, robust shells and a few small ones. The genus *Turritella* is represented by one species with only three individuals.

Among the pelecypods the genus *Glycymeris* is represented by the species *G.americana* (DeFrance) and *G. pectinata* (Gmelin), the species *G. subovata* (Say) being absent. *Arca* is very abundant being represented mainly by the species *A. "subsinuata"* Conrad. *Pecten* is rather common at all localities being represented by three species, one having a large shell. *Cardium robustum* Solander is present at nearly all localities as well as *Mulinia lateralis* Say. *Rangia clathrodonta* (Conrad) is present at two localities and *Corbicula densata* Conrad at one locality.

One small pelecypod apparently belonging to the genus *Anisothyris* is of special interest as it appears to be closely related to *A. obliqua* Gabb, a species described from brackish water deposits, usually referred to the Pliocene epoch, of the upper Amazon, Peru. The presence of the genera *Rangia*, *Corbicula* and *Anisothyris* indicates a tendency toward brackish water conditions whereas most of the other genera are marine forms that lived close to the former shore line.

Corals and Bryozoa occur at nearly all localities but are not listed in this paper.

COMPARISON OF THE FAUNAS OF PLIOCENE CROATAN SAND WITH THE FAUNAS OF THE UPPER MIOCENE

The upper Miocene faunas have many individuals of *Turritella* of the kind usually referred to the species *variabilis*, of *Arca "improcera"* Conrad and its variety *buccula* Conrad (like those in the Duplin marl at the Natural Well), of *Glycymeris subovata* (Say), of *Crassatellites undulatus* (Say), and of

Mulinia congesta Conrad (typical). All these forms are found in the upper Miocene at station 1/898, right bank of the Neuse River, 16 miles above New Bern or about 18 miles upstream from the Pliocene locality below James City.

The following species appear to have survived from the upper Miocene to the Pliocene without apparent change: *Corbicula densata* Conrad, a species occurring in the highest Miocene bed at Colerain Landing on the Chowan River, in the Pliocene at Wilmington, and at Nixons on the Waccamaw River; *Rangia clathrodonta* (Conrad), a species occurring in the highest Miocene bed at Colerain Landing, Chowan River, in the Pliocene at Cronley, in the upper bed at Lake Waccamaw, at Neills Eddy Landing, and at Walkers Bluff on the Cape Fear River. The specimens of *Panope goldfussii* Wagner var.?, from the Pliocene, about 2 miles below James City, have upright radiating lamellae on the inside of the shells; a very close, if not the same form, occurs in the upper Miocene at Suffolk, Va., at Tar Ferry, Wiccacon River, and below Mt. Gould Landing on the Chowan River, N. C.

The most closely related upper Miocene faunas to that of the Croatan sand occur in deposits farther north, at 1½ miles south of Poplar Point Landing, Roanoke River, and along the Chowan River, especially in the upper bed at Colerain Landing. At the latter place, in addition to the two species, *Corbicula densata* Conrad and *Rangia clathrodonta* (Conrad), previously mentioned, which also occur in the Croatan sand, such upper Miocene species as *Ptychosalpinx laqueata* (Conrad), *Glycymeris subovata* (Say), *Crassatellites undulatus* (Say), and *Arca "improcera"* Conrad like the form in the Duplin marl at the Natural Well, are present.

AGE AND CORRELATION OF THE FAUNAS

The faunas at the four localities (treating the 2 localities near Padgett as one) are believed to be of the same age and are assigned to the Pliocene Croatan sand. The faunas near Padgett lived farther south than those at other localities and consequently suggest a slightly warmer water condition. Many of the species begin in the Miocene and range upward to the Pliocene or even to the Recent, whereas other species begin in the Pliocene and are either confined to this horizon or continue on to a later time.

Species that are not known earlier than the Pliocene are: *Alectrion vibex* (Say), *Anachis obesa*, C. B. Adams, *Astyris lunata* (Say), *Odostomia impressa* (Say), *Turritella subannulata* Heilprin, *Littorina irroata carolinensis* Conrad, *Diodora alternata* (Say), *Arca "subsinuata"* Conrad, *Arca limula* Conrad, *Ostrea virginica* Gmelin, *Pecten eboreus* cf.*solariodes* Heilprin, *Pecten* cf. *P. sentis* Reeve, *Crassatellites gibbesii* (Tuomey and Holmes), *Phacoides waccamawensis delandensis* Mansfield, *Cardium isocardia* Linnaeus, *Chione cancellata* (Linnaeus) and others.

The absence of *Glycymeris subovata* (Say) and other species that become extinct at the end of the upper Miocene support the evidence of the Pliocene age of this fauna.

A fauna that has formerly been referred to the upper Miocene at Wilmington, represented by two collections, one from Station 2295, from sewer at corner of Nut and Mulberry Streets, collected by T. W. Stanton in 1891, and the other from Station 3610, from a stable back of Y.M.C.A. building, collected by T. W. Vaughan, in 1902, is considered to be Pliocene age, as nearly all the species at these two stations occur in beds now considered Pliocene, on and adjacent to the Cape Fear River.

However, among a few specimens collected by T. A. Conrad and deposited in the U. S. National Museum under the number 6112, labelled as coming from Wilmington, are *Crucibulum ramosum* Conrad, *Glycymeris subovata* Say, and *Panope reflexa* Say (typical). These are upper Miocene species and are like those in the Duplin marl at the Natural Well, N. C. If these species came from Wilmington they were taken from an older stratum than were the specimens collected at stations 2295 and 3610.

My opinion of the Pliocene age of the bed at Wilmington, based on the mollusks, is in harmony with the conclusion reached by F. S. MacNeil of the U. S. Geological Survey in his unpublished notes on the Arcas.

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CARDIUM NIXICOLLIS AND *OSTREA BATTENSIS* SUBSTITUTED FOR PREOCCUPIED NAMES

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In 1923, I described *Cardium vaughani*, from the Snow Hill member of the Black Creek formation (Upper Cretaceous), Snow Hill, Greene County, North Carolina (1). My attention has been called to the name *Cardium* (*Protocardia*) *vaughani* described by Shattuck in 1903 (2) from the Buda limestone of Texas. Although *Protocardia* is now generally accepted as a separate genus, the name *vaughani* as applied to the North Carolina shells must be regarded as preoccupied. I therefore substitute for it the name *Cardium nixicollis* from, the Latin words for Snow Hill ("Nix" = snow and "collis" = hill).

It also develops that my recently described *Ostrea johnsoni* (3) is preoccupied by *Ostrea johnsoni* Aldrich (4) from the Lisbon formation (Claiborne group, Eocene) of Alabama, and I rename it *Ostrea battensis*, from Batte Smith Bluff, the type locality.

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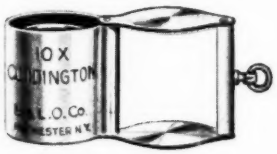

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